DOCUMENT RESUME

ED 353 972 IR 015 935

AUTHOR	Dills, Charles R.; Romiszowski, Alexander
TITLE	A Knowledge Acquisition System Based upon Structural Communication and Pattern Noting Technologies.
PUB DATE	90
NOTE	33p.
PUB TYPE	Information Analyses (070) -- Reports - Research/Technical (143)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Classification; Communication Research; Higher Education; *Intercultural Communication; *Models; Research Needs
IDENTIFIERS	Experts; *Knowledge Acquisition; Pattern Notes; *Structural Communication

ABSTRACT

This paper describes a four-dimensional model for the science of knowledge acquisition and a classification system in terms of these dimensions. A summary of the state of the art in terms of the cells generated in a four-dimensional representation of this classification system is presented. The need for better tools for conducting knowledge classification efforts in many of these cells is shown. One such tool, derived from a teaching model called Structural Communication, is described. It is argued that this tool would be useful in many of the cells for which no tools currently are available. An experiment using the Structural Communication approach to knowledge acquisition at the inter-cultural level is described. The resulting knowledge (i.e., data) is anlayzed using a method called Pattern Noting. The results from the data analysis are discussed in terms of what they show concerning the usefulness of the approach to knowledge acquisition, and recommendations for further research and application are made. (Contains 47 references.) (ALF)

A KNOWLEDGE ACQUISITION SYSTEM BASED UPON STRUCTURAL COMMUNICATION AND PATTERN NOTING TECHNOLOGIES

BY

CHARLES R. DILLS
RESEARCH FELLOW,
INSTRUCTIONAL DEVELOPMENT,
DESIGN, AND EVALUATION
SYRACUSE UNIVERSITY
SYRACUSE, NEW YORK

AND

ALEXANDER ROMISZOWSKI
PROFESSOR,
INSTRUCTIONAL DEVELOPMENT,
DESIGN AND EVALUATION
SYRACUSE UNIVERSITY
SYRACUSE, NEW YORK

ABSTRACT

This paper describes a four-dimensional model for the science of knowledge acquisition, and a classification system in terms of these dimensions. A summary of the state of the art in terms of the cells generated in a four-dimensional representation of this classification system is presented. The need for better tools for conducting knowledge classification efforts in many of these cells is shown. One such tool, derived from a teaching model called Structural Communication, is described. It is argued that this tool would be useful in many of the cells for which no tools currently are available. An experiment using the Structural Communication approach to knowledge acquisition at the inter-cultural is described. The resulting knowledge (data) is analyzed using a method called Pattern Noting. The results from the data analysis are discussed in terms of what they show concerning the usefulness of the approach to knowledge acquisition, and recommendations for further research and application are made.

THE KNOWLEDGE ACQUISITION PROBLEM

"Knowledge acquisition" is the acquisition of a domain of knowledge from its current location and its restructuring so as to make possible the insertion of this knowledge into a second location. Knowledge acquisition is not the only operation that can be performed on a domain of knowledge; the second operation is "knowledge creation", "knowledge production", or "Knowledge generation". "Knowledge generation" is the production of domain-specific content that was not previously present in that domain. A third type of operation on knowledge is often called "knowledge transmission". This term refers to the link between the knowledge producer and the knowledge user; in schools, this is called the "teaching/learning process"; in the larger cultural context, the terms "diffusion" and "adoption" are used. All of these terms refer to basically the same process, which is undertaken to deal with the same problem.

The problem is how to acquire a conceptual structure that was not previously available. At the applied, technical level, Knowledge acquisition is concurrently both the most important and the most problematic aspect of expert system development (McGraw and Harbison-Briggs, 1989). Knowledge acquisition efforts have failed to yield themselves to automation, or even to straightforward manual methodologies. It is the area of knowledge acquisition that forms the bottleneck within most large expert systems development projects. And not only a large proportion of development time, but also a large proportion of development costs, in most expert system development projects, must be devoted to knowledge acquisition efforts (Dills, 1989; Brule and Blount, 1989; McGraw and Harbison-Briggs, 1989).

The center of focus for the examination of this process in this paper is the transfer of conceptual structure from the mind of a human expert to the user of an expert system or other intelligent, knowledge-based machine. Three areas of scholarship within the knowledge-acquisition problem are relevant to our center of focus. These will be described, and the way in which they relate to the design of expert systems will be pointed out. Then an experiment will be described which explores an aspect of these areas using tools which are new to the area of knowledge acquisition for expert system building. Finally, implications and extensions of the experiment will be discussed, and recommendations concerning the use of the tools will be made.

KNOWLEDGE ACQUISITION TAXONOMY

The three areas of focus are related to each other and to the variables Depth of Structure, Type of Knowledge, Methods for Elicitation and Cooperative Arrangements in the accompanying figures.

The first area is that of culture. In this area, the problem becomes one of eliciting knowledge from the environment, both social and non-social. The people working on this problem are the anthropologists, a classic example of which is presented by H.G.Barnett in his book, Innovation: The Basis of Cultural Change (1953). Contemporary examples of the application of the findings from this area to the design of expert systems can be found in the archeological work of Benfer and Furbee (1989), the examination of current theorizing on the family as an institution (Sprey, 1988) the Italian project for socio-scientific knowledge acquisition (Bianco and Rolandino, 1988). Arandelovic (1986) has investigated the role of utopian thought (versus empirical thought) in knowledge acquisition. Within the applied technical realm, work such as that by Priest (1986) on the difference in cognitive strategies by novice and expert physics problem solvers belongs at this level.

The second area is that of child development and world-view/construct formation psychology and the sociology of knowledge. Here the problem becomes one of describing how a child elicits knowledge from the world around him, or how the adult learns from others or from the world, and how they structure this elicited knowledge. Currently, for example, work is being conducted using the work of Piaget (Siegel, 1978; Venn and Walkderdine, 1978; Blazek, 1979), Thomas Kuhn (Gagnon, 1978), Niels Bohr (Blazek, 1979) and others. Work has occurred in predicting whether or not knowledge acquisition will occur in the clinical setting, for example, by Sadowsky and Kunzel (1988), and both modern and classical theories of knowledge acquisition are described by Haroutunian-Gordon as she examines how psychology explains behavioral and cognitive change (Haroutunian-Gordon, 1988). Andersen (1984) has examined the acquisition of socio-linguistic knowledge by children. Knowledge acquisition in a developmental perspective as seen through the study of life-span development has been studied by Hoyer (1980). Knowledge acquisition as a social phenomenon, and as an activity driven by social interactivity, has been examined by Carley (1986). The problem of acquiring knowledge from machines, and in particular from computers, has been treated extensively under the heading of intelligent tutoring. Knowledge acquisition from an intelligent tutor has been treated by Mandl, et.al.(1988), and the same problem has been treated extensively by Wenger (1987) in so far as knowledge acquisition by students affects the design of intelligent tutors. Dills and Romiszowski (1990) are designing an instructional design model for interactive instruction based upon what is currently known concerning knowledge elicitation and acquisition by students from intelligent tutors and other intelligent, interactive sources. Ford, Petry, Adams-Webber and Chang (1990) have extended our understanding of the acquisition of deep-structured knowledge using Personal Construct theory. In a related approach, Dills and Miller (198) have used the semantic differential as a basis of deep-structure knowledge acquisition in the affective domain. Papers by Hoyer (1980), Fitzgerald (1980) and Dusek and Meyer (1980), dealing with psychological theories of knowledge acquisition within the framework of life-span development research, contain suggestions of potentially great value to theory and practice of knowledge acquisition and structuring within the third area of our focus, described below, which have never been exploited. The same can be said for the work of Carley (1986), especially through application of her model of knowledge acquisition to both cultural and technical Centers of Focus.

The third area of focus is the technological. Here the problem is visualized as how knowledge is acquired by one technician from another, or from written documents containing the knowledge to be acquired, or from data gathered from monitoring a process or technical instruments. This area of focus incorporates aspects of the first two areas, but modifies their import with the assumption that all parties involved in the knowledge acquisition process are aware of their involvement and are attempting to be cooperative (at least until something happens to negate this cooperation). This is the area that is usually associated with the term "knowledge engineering", but it also includes other areas, such as task analysis and content analysis within the instructional design and development paradigm, as well as other areas not normally thought of as related to knowledge engineering, such as auditing as practiced by accountants, legislative research as practiced by congressmen through junkets, open hearings and listening to lobbyists, and by spying as practiced by CIA intelligence analysts and the popularized versions of crime detectives and private eyes.

Reviews of techniques and heuristics within the third area of focus have been provided by a large number of authors, since this is a rapidly changing field. Anderson (1988) provides a review of the basic techniques employed in expert systems construction within the library science and information fields. Wiggs and Perez (1988) perform a similar service for the instructional development and design, instructional materials production, and cognitive science research fields. More in-depth coverage of knowledge acquisition within this area of focus, especially concentrating upon expert systems applications, are found in Wenger (1988), McGraw and Harbison-Briggs (1989), Brule and Blount 1989), Hart (1986), Parsaye and Chignell (1988), Martin and Oxman (1988), and Carrico, Girard and Jones (1989) and Harmon, Maus and Morrissey (1988). Case studies within this context are presented by many writers, including Brule and Blount (1989),Benfer and Furbee (1989) and De Jong (1988).

Work in all three areas of focus have in common that a clear distinction between the practice of knowledge acquisition and the practices of knowledge creation and knowledge transmission cannot be maintained. In a sense, these areas are merely different perspectives on the same problem. This can be seen within the first level of focus in the work of Barnett (1953), within the second level through the papers of Fitzgerald (1980) and Dusek and Meyer (1980), and on the third level through the writings of Hart (1986) and Ford (1989) on knowledge acquisition and those of Hutchinson (1984), on task analysis and instructional development models.

Work in knowledge acquisition can be classified according to other dimensions than that of cultural-to-technological. For example, knowledge acquisition efforts can be classified according to the depth the desired knowledge lies within the expert's (or other source's) cognitive structure. Knowledge may be classified as shallow knowledge, conceptual knowledge, deep-structured knowledge and meta-knowledge. Another, similar classification is given by Brule and Blount (1989), and is derived from Bateson (1972). This classification involves Learning Levels 0 through III. Level 0 involves responding in a fixed manner; Level I involves responding with varying items from a fixed set; Level II involves responding with various items from a set of generalized rules or principles; and Level III involves treating the rules or principles as metaphors.

The classification system for depth of knowledge to be used in this paper involves five categories. One is factual and procedural knowledge. The second is conceptual and principle. The third is structured and systematized knowledge, as with algorithmic knowledge. The fourth is world-view knowledge, or hermeneutic knowledge. The fifth level is neurologically or psychologically based or derived knowledge peculiar to the individual possessing it. A point needs to be made concerning different aspects of knowledge structures. The depth of knowledge on a particular topic is not uniform. This is obvious in a sense; terminology is at a more shallow level than is understanding of the interactions among process variables. But it is not so obvious, but is nevertheless true, that the cognitive knowledge of a topic and the evaluative structure for that same topic are often at different depths, and are somewhat independent of each other (Carley, 1986). Socially-compact groups of experts tend to develop identical cognitive structures concerning a given topic at a shallow or medium level, but have differing evaluations of that topic. Thus it may be useful, or even necessary, to categorize not only topics within knowledge structures by depth, but also to independently classify various aspects of each topic by depth. This will allow the application of the appropriate tool or technique not only to each topic, but also to each aspect of each topic.

Other categorizations of knowledge acquisition work are useful. For example, knowledge acquisition may be classified according to the social roles involved. The dimension describing such classifications will be called Cooperative Arrangements in this paper. One such classification would be the following: Elicitor cooperating with expert sharing a goal; elicitor with expert, not sharing a goal; elicitor with documents; elicitor with finitely-bounded real-world situation; elicitor with unbounded real-world situation; elicitor with unbounded metaphorical situation. Carley (1986) has found that social roles and other social variables strongly influence the manner in which knowledge acquisition occurs, as well as the manner in which the knowledge is structured once obtained.
Carley has developed a knowledge acquisition model based largely upon social interaction variables. A great deal more could be done along these lines, especially in some of the more exotic cells. A knowledge acquisition management tasks could be better structured than they currently tend to be by considering knowledge acquisition as a social function rather than as a technical writing function.

One exotic type of knowledge acquisition not included in any of the cells of our classification system, and which is best thought of in terms of the Cooperative Arrangements dimension, is knowledge acquisition from the self. Such a type of knowledge acquisition is clearly very closely related to internal knowledge creation. And a great deal of research has been devoted to what might be called internal knowledge linkage, or internal diffusion of knowledge. These functions have been studied from many perspectives over the years, such as the psychology of creative thought, memory retrieval, transfer of learning, and serendipity. However, these topics have not been widely applied to the knowledge acquisition problem. Obvious areas of application involve thought problems for the expert to use in the "difficult problem" approach to expert systems building, to introspection when an expert is attempting to find why he made a certain decision, and to the knowledge engineer when planning scenarios to present to the expert. It certainly also applies in the situation in which the knowledge engineer and the knowledge expert is the same individual. Several chapters of most contemporary textbooks on cognitive science or cognitive psychology are typically devoted to these issues. For example, <u>Cognitive Science: An Introduction</u> (Stillings, Feinstein, Garfield, Rissland, Rosenbaum, Weisler and Baker-Ward, 1989) goes far as to devote a complete chapter to problems of knowledge structure and self-learning machines, and several other chapters touch upon these questions. However, the tradition in psychology of studying introspective knowledge acquisition goes back at least to the introspective psychologists of the 1920s and 1930s. The problem of machine generation of rules from internalized performance data is being treated through inductive generation of theorems and heuristic rules in contemporary computer science (Carrico, Girard and Jones, 1989), and was treated by Dills and Popplewell within the context of intelligent inductive rule generators in military maintenance training simulators during the early 1980s (Dills and Popplewell, 1987).

A final dimension of importance in classifying knowledge acquisition efforts is by tools used by the knowledge elicitor. The most fundamental level is that at which only organizational and recording tools are used. Interview techniques, tape recorders, video recorders and flowcharting are at this level. The next level is that at which software tools are available. Most of these tools are very much like the previous set of tools, except, from the knowledge elicitor's point of view they are not manually operated (although they may be manually operated from the point of view of the expert from whom they are eliciting knowledge). The simplest of these tools merely let the expert enter knowledge directly into the knowledge base of the computer. The most complicated are the inductive tools, which generate rules from examples input by the expert (Carrico, Girard and Jones, 1988). Unfortunately, none of these tools can adequately deal with metaphors, world views, diagrams, photographs, multiple-expert disagreements, hunches, and so on. Therefore, there are many knowledge acquisition problems for which no adequate software tools exist. Therefore, the next level of tool use involves the use of language analysis, philosophical analysis, psychological testing, attempts to transmit intuitions, and just plain thought as tools. These tools are often inadequate, of course, but at the present time they are all that exist.

Thus, we can describe any knowledge acquisition study or project according to the cell it occupies within a four-dimensional matrix defined by the dimensions Area of Focus, Depth of Knowledge Sought, Social Roles and Tools available. Certain of these cells are well explored, and problems occupying them are quite amenable to commercial solutions. Others are on the borderlines of commercial feasibility, and books on the construction of expert systems expend efforts to show the project manager how to identify projects from these cells. They then explain why they should be avoided, in terms of the current state of the art (Martin and Oxman,1988; Carrico, Girard and Jones, 1989; Harmon, Maus and Morrissey,1988). Applications from still other cells at the moment are completely absent from the commercial world, either because there are no commercially feasible ways to deal with them, or because there is no commercial market for the type of knowledge acquired within these particular cells (or both).

The authors believe that eventually the state of the art of expert system utilization will develop to the point that knowledge acquired in all of the cells will be needed. When this occurs, the state of the art of expert system design, and of knowledge acquisition, will be required to advance to the point of being able to work with problems from all of the cells. Furthermore, any methods we develop capable of working in those cells which at the moment present the most difficult tasks will surely have significance for commercial projects. Therefore we are searching for knowledge acquisition methods to apply to deep-structured, world-view types of knowledge, which lie within the first area of focus.

One tool we believe to be likely to be useful at this level is derived from structural communication.

STRUCTURAL COMMUNICATION

Structural communication is a particular model of teaching. As such, it is a self-contained system, complete with information delivery system, remediation units, evaluation system and feedback mechanisms. Its uniqueness stems from two goals of the system: it strives to be both self-instructional and automatically administered, and it strives to engage the student in what most taxonomies of learning would term the "higher" stages of learning. Originating early in the 1960s as an attempt to merge certain of the theories of J.S.Bruner and B.F.Skinner, among others, the result has become a very flexible but structured model for teaching through guided dialogue (Romiszowski,1896; Eagen, 1976).

The basic unit of structural communication is the study unit. A study unit typically consists of six interdependent parts, although it is not necessarily inherent to the nature of structural communication that all of these parts be present in every single study unit. The six parts are as follows (Romiszowski 1986):

1. Intention. This tells the purpose of the study unit, presents its objectives, and serves as an advance organizer.

2. Presentation. This section introduces the student to the contents of the unit. It serves as the lecture, text assignment, or other information presentation element of the study unit.

3. Investigation. This section usually consists of some problems concerning the topic of the study unit that involve the information or concepts presented in the Presentation section. The student attempts to solve or otherwise deal with these problems, and presents this solution in the next section.

4. Response Matrix. The response matrix is a randomized array of between 10 and 35 elements. Each element represents a significant aspect of the topic of the study unit, an element from the presentation, a part of the solution to the problems from the Investigation section, or a distractor.

   The student must select the items that represent his answer to the question or solution to the problem posed in the previous section. The student does this by selecting the items in a particular sequence. For example, the task might represent the sequence of steps in solving a problem, or the topic sentences from an essay (in the order they would appear in the essay).

5. Discussion. The student is then provided feedback, comments or further dialogue with the instructor in the Discussion section. The actual mechanics of how this is accomplished varies considerably from application to application, and is largely a function of the medium being used (i.e., paper and pencil, computer, flash cards, audio tapes, etc.). In all cases, the general idea is the same, however. The comments the student will receive have already been prepared, and have been grouped according to the types of choices the student conceivably could make.

Suppose the student selected items 3, 6, 7, 8, 9, 2, 22, 18, in that order. Suppose the instructor agrees that items 3, 6 and 7 are important and should be first in the sequence of choices. The student will receive a message or messages telling him this, and possibly stating the reasons. If the instructor thinks that item 8 is a distractor, the student will receive a message telling him the instructor believes 8 should have been omitted, and telling why. An invitation to the student to disagree, or to discuss the matter in person or by e-mail, likely will be included. If the instructor agrees that items 9 and 22 both should have been selected, but in reverse order from that used by the student, the message will explain why this is so. Finally, suppose the instructor agrees that item 18 should be selected, and in its current position, but believes it has meaning only if selected along with item 23, which the student omitted. The message will explain the relationship between the two items, and argue for their joint selection.

6. Viewpoints. This section presents the instructor to the student. Here the instructor points out what aspects of the dialogue are subjective on his part; what parts are controversial and describes alternative viewpoints to those taken in the lesson. The student is also guided to further exploration of the study topic in this section.

It should be clear that often the choices evaluated in the student's response are value judgements or subjective decisions. This is not always so, but structural communication lends itself quite readily to the study of subjective questions, and so is often used in that context. In any case, the responses given to the student are tailored to his original response, and take the form of a dialogue between the student and the instructor concerning the student's response, just as at a higher level of structure, the entire study unit is a dialogue between the student and the instructor about the subject area under examination. The dialogue can be extended through several sequenced or related study units, forming a course or curriculum. Or it can serve as an isolated experience, either exploring a topic or serving as a final integrating experience following a more traditional introduction to a course.

While the six components of the study unit described above were the parts of the study guide as originally conceived, and still today can be found in almost all applications, they are not essential to the concept of structural communication. What is essential to this concept can be found by examining the function these parts play in the study unit. Finding this essence is important to the purposes of this paper because the use of structural communication as a knowledge acquisition tool requires modification of the above six-part format without violating the basic concepts involved, and using these concepts for a purpose other than teaching.

Structural communication, in any of its forms, may be defined as "the staged presentation of complex instructional materials to a student, together with devices to encourage his engagement in these materials at the higher stages of intellectual functioning, followed by an assessment of the intellectual structures in the student that have resulted from this engagement, further followed by corrective and supplemental feedback from the faculty, again presented at the same high level of intellectual functioning."

Not necessarily required by the concept of structural communication, but typically a practical necessity in order to implement the full set of goals and requirements of the concept, is the operation of the system in a self-instructional, self-paced mode, and is often delivered via a computer.

THE EXPERIMENT

An experiment was undertaken to determine whether or not the deep-knowledge structure of a subject-matter expert could be discovered through the use of the structural-communication knowledge-acquisition approach. Three stimulus sheets were prepared, each proposing to teach the topic, "American Popular Culture", to the junior and senior high school students of rural traditional areas of Formosa and Korea. Curriculum content was not described, but the use of high technology delivery systems, independent and self-directed study methods, criterion-based testing and other such uniquely-American teaching and learning strategies were specified in detail. One stimulus sheet was centered upon CBI, a library and interactive video discs; one used distance education via satellite; and one involved interacting with an expert system, a library and video discs.

Four experts were chosen from the students enrolled in a Syracuse University graduate class whose purpose was to explore the likely impact upon education of various innovative high technology communications systems, IDE 716. Three of these experts were students from Formosa, one was a student from Korea. These students were pursuing a master's degree in educational technology except one, who was pursuing a similar degree in the department of speech pathology.

The remaining students in IDE 716 and their instructor acted as knowledge engineers (two American students and a British professor). Their ultimate task was to discover the structure and content of national belief system concerning education of the Taiwanese and Korean peoples. Their immediate task, which was assumed to be the first step towards accomplishing this task, was to discover the structure and content of the belief system held by each of the subject-matter experts within the class. They used the structured-communications approach to do this.

Each knowledge engineer interviewed each of the four subject-matter experts. All knowledge engineers used an identical 57-item selection matrix and annotation sheet, but each knowledge engineer used a different proposal description.

Each interview was based upon the same scenario. The scenario claimed that the expert's nation had issued an RFP to companies in the United States, asking them to submit a proposal for a course explaining American popular culture to the public school students of their country. The company is to describe the method for teaching the course as well as content, and high-technology methods are to be used whenever feasible. The project will be financed by an American government organization, and will serve as a model of technology utilization, so cost limitations are not to be considered a factor in deciding among proposals. Each knowledge engineer represents a different company, and the proposal descriptions are the technological components of each company's response to the RFP. Each knowledge engineer asks the expert's help in determining whether or not anything contained in the proposal conflicts with any practice or belief concerning educational practices within the rural, traditional view of education held by the students, teachers or parents of the regions targeted by the proposal.

Subject-matter experts were instructed to read the proposal before and again during the interview with any given knowledge engineer. Then, with the proposal before them, they were to read each of the 57 items on the selection matrix and decide if the item applied to the current proposal and also if the item violated some belief, custom or practice of the culture the expert represented. If so, the expert was to draw a line through the item on the selection matrix, and to describe the reason for rejecting the item in a sentence or short paragraph on the annotation sheet. Thus, in this particular version of structured communication, the expert was given what in traditional writings on structured communications is called the case study and the selection matrix, and was asked to make selections on the selection matrix and write the feedback discussion themselves.

Following the completion of the selection matrix and feedback comments, the knowledge engineer would read it over and conduct a de-briefing interview with the expert. During this interview, which was open-ended and free form, questions about items not eliminated on the selection matrix, as well as about items eliminated, were to be asked. No record of this interview was kept except to the extent that it resulted in the subject-matter expert modifying the written response record (when instructions had not been understood, or a question arose as to the meaning of an English phrase on the selection matrix, for example). The interviews were discussed in class, however.

The selection matrices and annotation sheets were signed by both the knowledge engineer and the subject-matter expert following each interview, and were turned over to the author for processing.

Processing occurred in several sequential steps. The first was to tabulate the items on the selection matrix that were eliminated by each of the experts, and to determine the degree to which they agreed. The degree among experts across knowledge engineers, and of all experts within a given country, were also determined (thereby also determining the degree of disagreement).

Next, item reduction was performed. This process consisted of combining items for which the explanations entered on the annotation sheets were identical, or very close to being the same. The explanations were then re-stated in such a way as to attempt to elucidate the principle or structural component of the underlying knowledge structure. This was a qualitative, not a quantitative process, and is subjective. Nevertheless, the data in the pilot study described here seems clear-cut enough to justify this procedure.

OUTCOMES

SUBJECT-MATTER EXPERT

KNOWLEDGE ENGINEER	1	2	3	4	TOTAL
A	11	8	16	5	40
B	8	18	17	10	53
C	7	15	25	12	59
TOTALS	26	41	58	27	
	KOREA	FORMOSA	FORMOSA	FORMOSA	

NUMBER OF DISCOVERED DIFFERENCES

NUMBER OF RESPONSES: The number of responses obtained by each of the three knowledge engineers differed. This was true not only between subject-matter experts from different countries, by from experts within a single country (Formosa). For example, one engineer received 8, 16 and 5 responses from the three experts from Formosa. A second engineer received 18, 17, and 10 responses, and the third engineer received 15, 25 and 12 responses. While it is inappropriate to compare responses of subject-matter experts across engineers quantitatively, since they were responding to different problems with each of the engineers, a qualitative comparison shows that some subject-matter experts have a tendency to respond more frequently than do others. This fact indicates a need to use multiple experts, and also a need to follow up the procedure with de-briefing interviews and a further round of structured communication problems in order to probe the deep-structure knowledge to a greater depth. It also probably indicates a need for more probing when using other methods of knowledge acquisition, since this tendency on the part of subject-matter experts is probably not limited to the structured-communication environment.

CONSISTENCY ACROSS EXPERTS: Each subject-matter expert was faced with the identical problem from a given knowledge engineer. If we assume that each expert is identically informed concerning the culture and educational institutions of his or her country, we would expect that all experts would respond identically on a given problem. The variation among knowledge engineers should not matter, since for a given problem, only a single knowledge engineer is involved. However, this did not happen. The degree to which consistency of response failed to occur can be taken as a measure of the error of measurement of the procedure, and its inverse as the measure of inter-subject reliability of the procedure. One knowledge engineer obtained 31 responses from three subjects from Formosa. Of these, 12 were given by two or more experts, and none were given by all three. This represents a 38.7% duplication. Thus the inter-subject reliability for that problem can be taken as .387. For another engineer, with a different problem, over the same experts, 33 responses were obtained, with 11 being given by two or more experts, and two being given by all three experts. This produces an inter-subject reliability of .333. The third engineer received 21 responses, with 8 responses being given by two or more experts and none given by all three experts. Again, this was a different problem from that used by the other two engineers. This resulted in an inter-subject reliability of .381. The average of these reliabilities is .367. The figure given when the data is from each engineer is combined is .381. Thus, the inter-subject reliability for the method can be considered to be approximately around one third.

A follow-up experiment is suggested by this data. A second round of interviews could be conducted by the same knowledge engineers and the same experts, asking each expert to comment upon the responses of the other experts. Thus it would be determined whether or not the low reliability value is a result of disagreement among experts or is a result of individual differences in responding. If it is a result of individual differences in responding, then such second-round interviews should be routinely used in order to obtain consistent responses and to obtain them from a consistent depth in the experts' mental structures. However, if the differences in responding is a result of differences in the mental structure of the experts, then some other method needs to be used to determine the actual situation. The engineers would be on their way toward mapping the cognitive structure of the experts using the method under investigation, but this would not necessarily lead to an accurate and usable map of the reality the mental structures mirror. Unfortunately, this follow-up study could not be performed because the experts and some of the knowledge engineers are no longer available for conducting the study. But this approach should be followed in future experiments.

<u>CONSISTENCY ACROSS KNOWLEDGE ENGINEERS</u>: No attempt was made to determine the degree of reliability of results across knowledge engineers, since each knowledge engineer used a different problem than did any other. In the future, some attempt should be made to determine the degree of this consistency. This would be determined by an experiment similar to the one described in the current paper, but with all knowledge engineers using the same set of problems with the same experts.

<u>COMPOSITE PATTERN NOTES</u>: Composite Pattern Notes were produced in a variety of ways. Composites were produced for each subject-matter expert across engineers, and for each engineer across experts for a given country. Finally, Composites were produced for each country using all experts from that country. These, again, were not verified for expert agreement using a Delphi or some similar method. It is recommended that in the future this be done.

The country Composites were compared to determine if the two countries were represented by distinctly different mental structures in the minds of the experts. All experts combined responded to 47 out of 57 items. Experts from Formosa responded to 43 items, and the expert from Korea responded to 18 items. Three of the items responded to by the Korean expert were not responded to by the Formosans, and 28 of the items responded to by the Formosans were not responded to by the Korean. Therefore, there were 31 items out of 47 that serve to differentiate the two countries. This represents 66% of the items responded to. This means that two-thirds of the items receiving a response are discriminatory items. However, it is not true that two-thirds of the responses were discriminatory. There were a total of 151 responses by experts. Of these, 82 were to items that were later discovered to be discriminatory. This represents 54.3% of the total number of responses. So while two-thirds of the items were discriminatory, only about half of the responses were discriminatory.

A Delphi or some similar method should be used to verify that differences in the Composite Pattern Notes for the two countries truly reflect conceptual differences in the minds of the experts are a result of individual differences in response generation, or in the depth from which the responses were extracted from the different experts.

QUESTION GENERATION: Assuming it to be found that differences among the Composite Pattern Notes for the two countries represent real differences in the mental structures of the experts, the next round of knowledge acquisition can occur. This effort would explore further the results already obtained. The direction of this exploration would be determined by the motivating needs of the project for which the knowledge is being acquired, and could either be directed toward the production of more detailed knowledge or the verification of generalizations. In either case, response items can be generated from the Composite Country Pattern Notes, and these in turn can be used to outline the scenarios.

FUTURE RESEARCH

Several studies need to be carried out in the future in order to determine the exact circumstances in which various versions of structured communications are appropriate for knowledge acquisition. The first such experiment, of course, is to extend the present study to the second stage, in which questions are generated from the present data and presented to the same subjects to try to map the cognitive structure to a deeper level. A second, and related, experiment is to present the same stimulus material used in the present experiment to new subject-matter experts in order to determine the consistency of their views with those of the present experts. If significant differences are found, the use of structured communications in a Delphi-type procedure could be tested as a way to reconcile differences among experts.

Finally, a series of studies are contemplated in which the structured communications forms that are found to be the most useful in knowledge acquisition tasks would be combined with various versions of computer-mediated communications systems, such as E-Mail or networked files on IBM mainframe CMS systems. Attempts would then be made to use structured communications to reconcile or acquire knowledge in a number of situations of potential value. For instance, it could be used to acquire knowledge on a topic from a number of experts in different locations. It could be used to acquire a consensus of expert opinion on a topic from the entire expert community of the United States. It could be used to reconcile expert opinions among geographically separated experts who differ in their viewpoints. And it could be used in a particular community (such as a classroom, a school, a company or a research group) to build in an evolutionary fashion a knowledge structure representative of the entire group.

The questions to be asked in these experiments are:

(1) whether the application works.

(2) under what conditions does it work better (faster, cheaper, more efficiently obtain greater depth, attain easier reconciliation, etc.) than do alternative knowledge acquisition methods?

(3) can unique knowledge acquisition goals be achieved that cannot be achieved any other? and,(4) are there better analytical methods available for use in analyzing the data and formulating the resulting knowledge structure than pattern noting, especially within the context of computer-mediated communications?

Another area that needs attention is the area of the knowledge-acquisition process from the point of view of the expert whose mental structures are being studied. The importance of this is shown by representing the knowledge-acquisition process in terms of the Shannon-Weaver communications model

(Shannon and Weaver, 1964). In this model, the process consists of a transmitter and a receiver, with a transmission medium between, and with static or other noise inherent to the transmission line. The subject-matter expert is the transmitter, and the knowledge acquisition expert is the receiver. But how does the expert decide what to transmit? How does his knowledge structure and other mental structures affect this decision? And how does he view the task he is engaged in? There has been a wide range of answers to these questions exhibited within contexts in which I have worked. Sometimes the expert is [illegible] against his will, sometimes the expert has originated the project. Sometimes the expert wishes to hold back certain information, or all information beyond a certain depth of expertise. Sometimes the expert tells the knowledge acquisition expert these things, sometimes these things are held back and must be guessed.

The Johardi Window, used to model inter-personal communications (Coscarelli and Stonewater, 1984; Luft, 1961) might be a useful tool for picturing the questions raised by introducing the expert's personality as a factor in what knowledge is accessed. In the johardi window model, each participant in the communications process is speaking through a window. This window is partially open, and has a shade. Behind the window is the person's mind. Part of that mind is directly transmitted through the open window. Part is transmitted, but in a distorted form, through the glass of the closed part of the window. And part is never transmitted, because of the blind. The same happens to information arriving at the window from outside. Part is admitted, part is admitted in a distorted form and part is blocked. Further, the window and the blind are movable, partially at the control of the person behind the window, and partially by other factors. Thus when the person is talking to a subordinate the window is open a certain amount, but when talking to his superior, it is open a different amount. How does this window function between an expert and a knowledge acquisition specialist? What factors of management, of personality, of procedure, and of acquired ownership of the project, effect the window? How do they effect it?

The phenomenology of the expert needs to be examined, especially in relationship to knowledge acquisition projects for expert system production. For example, how does an expert tend to understand the knowledge acquisition process? How does an expert understand the nature of his own expertise? As far as I have been able to discover, these questions have never been investigated. One way in which do conduct such an investigation would be through the use of conventional interview techniques, or to ask an expert to write a essay discussing his view of the matter. But if more than superficial knowledge of the expert's feeling and viewpoint are to be acquired, a more subtle and sophisticated approach will be needed.

The structural communication approach could be used as a research methodology for investigating these questions relating to the expert's view of himself, his expertise and the acquisition process. The procedures to carry out these studies would be much like the procedures used in the experiment described earlier.

REFERENCES

Andersen, E.S. (1984). The Acquisition of Socio-linguistic Knowledge: Some Evidence from Children's Verbal Role-Play. Western Journal of Speech Communication. 48(2), 125-144.

Anderson, P.F. (1988). Expert Systems, Expertise, and the Library and Information Professions. Library and Information Science Research. 10(4), 367-388.

Arandelovic, J. (1986). Empirical Research and Utopian Thought. Sociologija. 28(1-2), 83-101.

Barnett, H.G.(1953). Innovation: The Basis of Cultural Change. New York: McGraw Hill.

Bateson, G. (1979). Mind and Nature: A Necessary Unity. New York: Dutton.

Benchimol, G., Levine, P. and Pomerol, J.C. (1987). Developing Expert Systems for Business. London: Kogan Page.

Benfer, R.A. and Furbee, L. (1989). Knowledge Acquisition in the Peruvian Andes. AI Expert. November, 1989, 22-29.

Bennett, J.G. and Hodgson, A.M.(1968). The Progress of Educational Technology. Systematics. 6(2), 95-113.

Bianco, M.L. and Rolandino, R.M. (1988). Quaderni di Sociologia. 34(11), 29-60.

Blazek, B. (1979). Can Epistemology as a Philosophical Discipline Develop into a Science? Dialectica. 33(2), 87-108.

Brule, J.F. and Blount, A. (1989). Knowledge Acquisition. New York: McGraw-Hill.

Carley, K. (1986). Knowledge Acquisition as a Social Phenomenon. Instructional Science. 14, 381-438.

Carrico, M.A., Girard, J.E. and Jones, J.P. (1989). Building Knowledge Systems: Developing and Managing Rule-Based Applications. New York: McGraw-Hill Book Company.

Coscarelli, W.C. and Stonewater, J.K. (1984). Psychological Typologies and the Dynamics of Consultant Relationships. In R.K.Bass and C.R.Dills (eds.) Instructional Development: The State of the Art, II. Dubuque, Iowa: Kendall Hunt.

De Jong, T. (1988). Knowledge Acquisition for an Integrated Project Management System. Information Processing and Management. 24(6), 681-691.

Dills, C.R. (1989). Specifications for the Knowledge Acquisition Plan for the 20F16 Intelligent Training Platform. Unpublished document. Syracuse, New York: Syracuse University.

Dills, C.R. and Miller, J.(1986). A Study of Teacher Burnout Among Florida Elementary Teachers Using the Semantic Differential: A New Methodology. Paper presented at Annual Meeting of the Eastern Educational Research Association, Miami Florida.

Dills, C.R. and Popplewell, H. (1987). Individualized Instruction Rule Generation During Instruction on Large-Scale Integrated Intelligent Maintenance Trainers. Paper presented at the Annual Meeting of the Canadian Educational Communications and Technology Conference, Saskatoon, Saskatchewan, Canada.

Dills, C.R. and Romiszowski, R. (1990). The Application of Formal Design Theories to the Production of Videodisc/CBI Instructional Systems. Paper presented at the Annual Meeting of the Association for the Development of Computer-Based Instructional Systems.

Dusek, J.B. and Meyer, W.J. (1980). A Dialectic Analysis of Learning Theory Contributions to Understanding Human Development. Human Development. 23, 382-388.

Egan, K. (1976). Structural Communication. Belmont, California: Fearon Publishers.

Fields, A. (1982). Getting Started: Pattern Notes and Perspectives. In D.H.Jonassen (ed.) The Technology of Text: Principles for Structuring, Designing, and Displaying Text. Englewood Cliffs, New Jersey.

Fitzgerald, J.M. (1980). Learning and Development: Mutual Bases in a Dialectical Perspective. Human Development. 23, 376-382.

Ford, K.M. (1989). Knowledge Acquisition for Expert Systems. Paper presented at FLAIRS-89 Conference, Orlando, Florida. April 4, 1989.

Ford, K.M., Petry, F.E., Adams-Webber, J.R., and Chang, P.J. (1990). An Approach to Knowledge Acquisition Based on the Structure of Personal Construct Systems. Unpublished Manuscript.
Gagnon, M. (1978). Piaget and Kuhn on the Evolution of Knowledge. A Comparison. Dialogue. 17(1), 35-55.

Harmon, P., Maus, R., and Morrissey, W. (1988). Expert Systems: Tools and Applications. New York: John Wiley and Sons, Inc.

Haroutunian-Gordon, S. (1988). Explaining Change in Psychology The Road Not Taken. Human Studies. 11(4), 389-418.

Hart, A. (1986). Knowledge Acquisition for Expert Systems. New York: McGraw-Hill.

Hodgson, A.M. (1974). Structural Communication in Practice. In APLET Yearbook of Educational and Instructional Technology 1974/1975. Howe, A. and Romiszowski, A.J. (ed.) London: Association for Programmed Learning and Educational Technology.

Hoyer, W.J. (1980). Information Processing, Knowledge Acquisition and Learning: Developmental Perspectives. Human Development 23, 389-393.

Hutchinson, T.E. (1984) Metamethodology. In R.K.Bass and C.R.Dills (eds.), Instructional Development: The State of the Art, II. Dubuque, Iowa: Kendall Hunt.

Luft, J. (1961). The Johari Window. Human Relations Training News. 5, 6-7.

Martin, J. and Oxman, S.(1988). Building Expert Systems: A Tutorial. Englewood Cliffs, New Jersey: Prentice-Hall

Mandl, H. (1988). Knowledge Acquisition in Intelligent Learning Environments. International Journal of Educational Research. 12(8), 791-873.

McGraw, K.L. and Harbison-Briggs, K. (1989). Knowledge Acquisition: Principles and Guidelines. Englewood Cliffs. New Jersey: Prentice Hall.

Parsaye, K. and Chignell, M. (1988). Expert Systems for Experts (1988). New York: John Wiley and Sons, Inc.

Priest, A.G. (1986). Solving Problems in Newtonian Mechanics. Instructional Science. 14, 339-355.

Pusch, W., and Slee, E. (1990) .Structural Communication: A Forgotten Application of Cognitive Theory of Instruction. Instructional Developments: A Journal of the School of Education at Syracuse University. 1(2), 11-16.

Romiszowski, A.J.(1986,1990). Developing Auto-Instructional Materials: From Programmed Texts to CAL and Interactive Video. London: Kogan Page.

Sadowsky, D. and Kunzel, C. (1988). Predicting Knowledge Acquisition in Two Clinician Groups: Rethinking the Standard Paradigm. Knowledge in Society. 1(2), 58-68.

Shannon, C.E. and Weaver, W. (1964). The Mathematical Theory of Communication. Urbana, Illinois: University of Illinois Press.

Siegel, H. (1978). Piaget's Conception of Epistemology Educational Theory. 28(1), 16-22.

Sprey, J. (1988). Current Theorizing on the Family: An Appraisal Journal of Marriage and the Family. 50(4). 875-890.

Stillings, N.A., Feinstein, M.H., Garfield, J.L., Rissland, E.L., Rosenbaum, D.A., Weisler, S.E., and Baker-Ward, L.B. (1989). Cognitive Science: An Introduction. Cambridge, Massachusetts: The MIT Press.

Venn, C. and Walkderdine, V. (1978). The Acquisition and Production of Knowledge: Piaget's Theory Reconsidered. Ideology and Consciousness. 3(Spring), 67-94.

Wenger, Etienne (1987). Artificial Intelligence and Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge. Los Altos, California: Morgan Kaufmann, Publishers, Inc.

Wiggs, C.L. and Perez, R.S. (1988). The Use of Knowledge Acquisition in Instructional Design. Computers in Human Behavior. 4(3), 257-274.

ELEMENTS	PERSON WHO USES OR WRITES ELEMENT		
CASE STUDY	INSTRUCTOR	KNOWLEDGE ENGINEER	KNOWLEDGE ENGINEER
WHO COMPLETES RESPONSE MATRIX	STUDENT	SUBJECT MATTER EXPERT	KNOWLEDGE ENGINEER
WHO WRITES FEEDBACK COMMENTS	INSTRUCTOR	SUBJECT MATTER EXPERT	SUBJECT MATTER EXPERT
PURPOSE	TO TEACH STUDENT	TO CREATE COPY OF WORLD-VIEW PICTURE OF SME FROM SCRATCH	TO INCREMENTALLY IMPROVE/ENRICH WORLD-VIEW OF KNOWLEDGE ENGINEER

COMPARISON OF USE OF ELEMENTS IN THREE STRUCTURAL COMMUNICATION CONFIGURATIONS

DEPTH OF KNOWLEDGE

1. FACTUAL AND PROCEDURAL
2. CONCEPTUAL AND PRINCIPLE
3. STRUCTURED AND SYSTEMATIZED
4. WORLD-VIEW (HERMENEUTIC)
5. NEUROLOGICAL/PSYCHOLOGICAL

VARIABLES (DIMENSIONS) OF KNOWLEDGE ACQUISITION

1. DEPTH OF STRUCTURE

2. TYPE OF KNOWLEDGE

3, METHODS FOR ELICITATION

4. COOPERATIVE (SOCIAL) ARRANGEMENTS

AREAS OF FOCUS

1. CULTURE

2. PSYCHOLOGY AND SOCIOLOGY OF KNOWLEDGE

3. TECHNOLOGY

SOCIAL ROLES

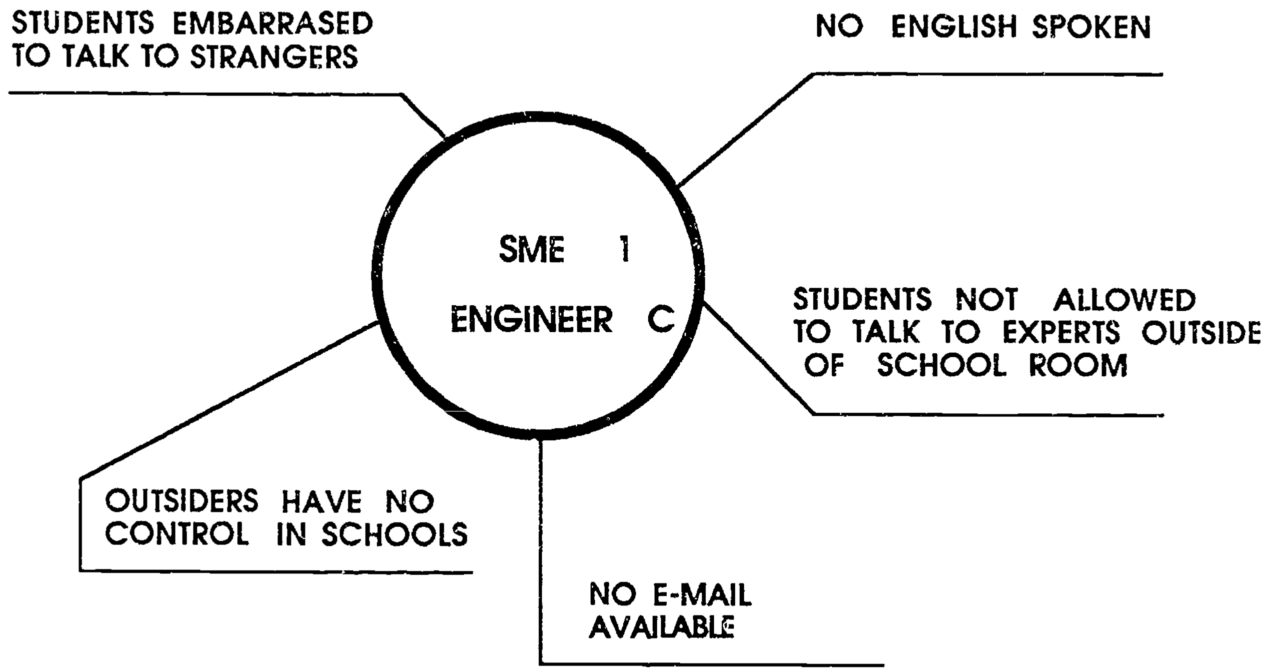
1. ELICITOR WITH EXPERT, SHARING A GOAL
2. ELICITOR WITH EXPERT, NOT SHARING A GOAL
3. ELICITOR WITH DOCUMENTS
4. ELICITOR WITH FINITELY-BOUNDED REAL-WORLD SITUATION
5. ELICITOR WITH UNBOUNDED REAL-WORLD SITUATION
6. ELICITOR WITH METAPHORICAL SITUATION

TOOLS

1. ORGANIZATIONAL AND RECORDING TOOLS
2. SOFTWARE TOOLS
3. PHILOSOPHICAL, PSYCHOLOGICAL AND LINGUISTIC TOOLS

KINDS OF KNOWLEDGE

1. SENSORY
2. EMOTIVE
3. BEHAVIORAL
4. VERBAL
5. QUANTITATIVE
6. INTUITIVE



PATTERN NOTING ANALYSIS OF OUTCOME OF INTERVIEW BETWEEN SME 1 AND KNOWLEDGE ENGINEER C