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ABSTRACT

This article describes the results of a three-month experiment in the use of computer-based semantic networks for curriculum development. A team of doctoral and master's degree students developed a 1200-item computer database representing a tentative "domain of competency" for a proposed MA degree in Workforce Education and Lifelong Learning (WELL). The team gathered descriptions of knowledge that might be relevant to the proposed degree from state and national reports, existing course syllabi, textbooks, and interviews with subject matter experts. Using SemNet, a Macintosh-based program for constructing and analyzing semantic networks, they explored methods for organizing these decisions as a "map" of related skills and ideas that would in turn serve as a framework for a WELL curriculum. The team explored various methods for using domain maps to define course content, to recommend learning activities, and to provide academic counseling to prospective WELL students. Among the innovative methods for conducting this experiment in curriculum development was the use of computer software for synchronous conferencing, which allowed team members to collaborate in evaluating and integrating domain maps. (Contains 32 references.) (Author)

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Computer-Based Mapping for Curriculum Development

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Computer-Based Mapping for Curriculum Development[1]

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Abstract

This article describes the results of a three-month experiment in the use of computer-based semantic networks for curriculum development. A team of doctoral and master's degree students developed a 1200-item computer data base representing a tentative "domain of competency" for a proposed MA degree in Workforce Education and Lifelong Learning (WELL).

The team gathered descriptions of knowledge that might be relevant to the proposed degree from state and national reports, existing course syllabi, textbooks, and interviews with subject matter experts. Using *SemNet*, a Macintosh-based program for constructing and analyzing semantic networks, they explored methods for organizing these descriptions as a "map" of related skills and ideas that would in turn serve as a framework for a WELL curriculum. The team explored various methods for using domain maps to define course content, to recommend learning activities, and to provide academic counseling to prospective WELL students. Among the innovative methods for conducting this experiment in curriculum development was the use of computer software for synchronous conferencing which allowed team members to collaborate in evaluating and integrating domain maps.

Curriculum development is a major concern at all levels of education since it encompasses the goals of learning, the scope and sequence of subject matter content, the interaction of the learners with the content, and methods for assessing the outcomes. In recent years, curriculum development has become a much more complex task because of the explosion of human knowledge, the increased variety of skills required for successful employment and citizenship, and the greater fractiousness of political debate over content and methods.

A steady stream of widely-cited curriculum theorists (Tyler, 1950; Taba, 1962; Hartley, 1968; Tanner and Tanner, 1980; Doll, 1989) have proposed criteria that might guide decision making in the curriculum planning process. However,

1 *SemNet* is a trademark of the SemNet Research Group, a California Limited Partnership. *Macintosh* is a trademark of the Apple Computer Company, Inc. *Timbuktu* is a trademark of Farallon Computing Inc. The authors wish to thank Barbara Allen, Carol Breckenridge, and Stuart Grossman for their assistance in preparing this manuscript. Organizational affiliations are described for purposes of identification only; the opinions expressed in this report are those of the authors and do not necessarily represent reflect the policies of agencies or organizations cited herein, or of San Diego State University. Development of this article was partially supported by a grant from the Applied Behavioral and Cognitive Sciences, Inc. with funds from the William and Flora Hewlett Foundation.

curriculum development is hardly an objective or purely scientific enterprise that follows universal principles or a predetermined planning process.

Decision making in curriculum development is a function of tradition, historical and philosophical perspectives, social and cultural influences, and the political exigencies of the day. While all of these are important to the curriculum development process, there is a dearth of tools for systematic data gathering and rational analysis that might inform and support the kind of collaborative decision making that is essential for effective results. Such tools are especially needed in educational institutions that subscribe to contemporary theories of decentralized authority and management.

Using Maps for Curriculum Development

Fundamentally, this report addresses the need for new tools by investigating an experimental process for generating curriculum maps from concept maps. Since there is great diversity in the terminology that is used to describe conceptual and curricular structures, we begin by defining three types.

Curriculum maps are representations of the structures employed by schools and other educational organizations as a means for assigning activities and allocating time intended to facilitate the development of student knowledge.

Concept maps are representations of the structure of "public" conceptual systems, where "public" implies shared use of common terminology and language including—but not restricted to—forums such as publications, lectures and other presentations, discussions, and other formal and informal communication.

Cognitive maps are representations of the internal mental structures of individuals that emphasize the meaning that individuals attribute to concepts; they may be used to describe expert knowledge, to diagnose or assess an individual's understanding of a knowledge domain, or to compare and contrast differences in the conceptual systems of individuals or groups.

Curriculum Maps

Among the obstacles to systematic curriculum development is the problem of sifting through large numbers of documents relevant to curriculum decisions: state and national reports and curriculum frameworks, text books, journals, existing syllabi and the like. Flowcharting and mapping techniques have been used for planning, implementing and evaluating the curriculum but computers have only recently been used to process the large amounts of information that are generated during curriculum development.

Fenwick English (1980) proposed the technique of "curriculum mapping" as a means of quality control. His approach emphasizes assessment of the extent to which learning tasks and/or learning time conform to standards delineated in a curriculum guide, and attempts to determine the extent to which what is actually taught is congruent with measures of achievement. A step-by-step guide for curriculum mapping can be found in Donald F. Weinstein's *Administrator's Guide to Curriculum Mapping* (1986). Curriculum mapping can be used to determine potential corrections and improvements in school programs. Essentially, English's use of the term "curriculum mapping" refers to a comparison (mapping) of an idealized curricular structure with an attempted implementation and we think, therefore, that a better term for the process he describes would be curriculum audit mapping. This is consistent with English's later work in curriculum auditing (English, 1988). We reserve the term curriculum map for each of the two structures that are being compared: the desired/required and the actual. Our report is concerned with methods for developing and using maps of the desired/required curriculum.

Another strategy for curriculum development and management can be found in Warren Hathaway's (1989) use of PERT-like networks to organize the curriculum and to manage instructional resources. PERT (Program Evaluation and Review

Technique) charts are widely used in business and industry to plan and monitor parallel activities in support of common goals or outcomes. They are used to allocate and monitor resources, to estimate completion dates, and to determine ongoing progress. Hathaway's contribution was to show that such techniques could be applied to the achievement of instructional goals as well as the construction of buildings or organization of factories.

Concept Maps

In contrast to the systems proposed by English and Hathaway, which are directed towards institutionalized implementation and management, are approaches that focus on the conceptual organization of curricula. Typical is the work of Novak and Gowin (1984) who have demonstrated how concept mapping can be used to plan a total curriculum as well as specific instructional activities.

Before we discuss the use of concept maps for curriculum development, let us briefly examine the variety of concept maps and mapping strategies proposed in literature. Concept maps demonstrate structural relationships between concepts. Several types of structures/representations such as spatial maps (Holley and Dansereau, 1984), nested hierarchical maps (Miller, 1969; Johnson, 1967), graphic maps (Anderson and Bower, 1973; Quillian, 1968; Rumelhart et al, 1972) have been described. Preece (1978) has reviewed the research on various organizations of concepts in these maps. Although the different types of maps reflect different theories of semantic structure, Friendly (1977) suggested that the models were actually quite similar in their use of propositions and semantic distance data. Nevertheless, there are differences in the methods and conventions used to construct concept maps. We will briefly examine three approaches described by Holley and Dansereau (1984): networking, mapping, and schematizing.

Holley and Dansereau argue that networking is a fundamental tool for acquiring and developing individual knowledge. During acquisition, the student identifies important concepts or ideas in the material and represents their inter-relationships and structure in the form of a network map. Students are taught a set of named links that can be used to code relationships between ideas. The networking process emphasizes the identification and representation of (1) hierarchies, (2) chains of logic, (3) clusters. An example of a network is shown in **Figure 1.**

Mapping is another technique used to represent knowledge. Several researchers have investigated concept mapping strategies. An elementary approach to mapping proposed by Hauf (1971) involves placing the central idea of a passage near the middle of a note page and attaching the subsidiary ideas in a concentric fashion, thus producing a product resembling a road map. According to Holley and Dansereau, mapping requires a set of relational conventions or symbols. In their

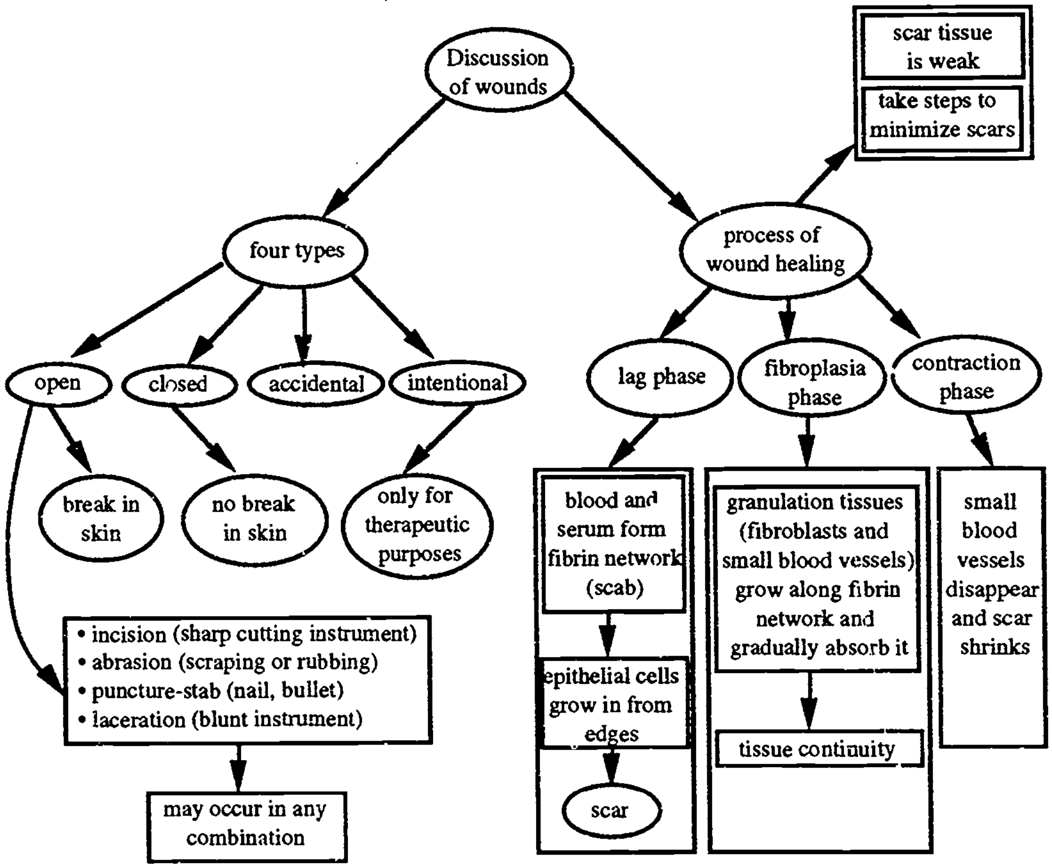

Figure 1. Example of a network of a chapter from a nursing textbook (from Holley and Dansereau, 1984).

research, they provided students with symbols depicting seven fundamental relationships:

1. B *is an instance of* A;
2. B *is a property of* A;
3. A *is similar to* B;
4. A *is greater than or less than* B;
5. A *occurs before* B;
6. A *causes* B; and
7. A *is the negation* of B.

An example of a concept map developed by Stewart, Van Kirk, & Rowell (cited in Holley and Dansereau, 1984) is shown in **Figure 2**. For a review of relational descriptors see Allen and Hoffman (in press).

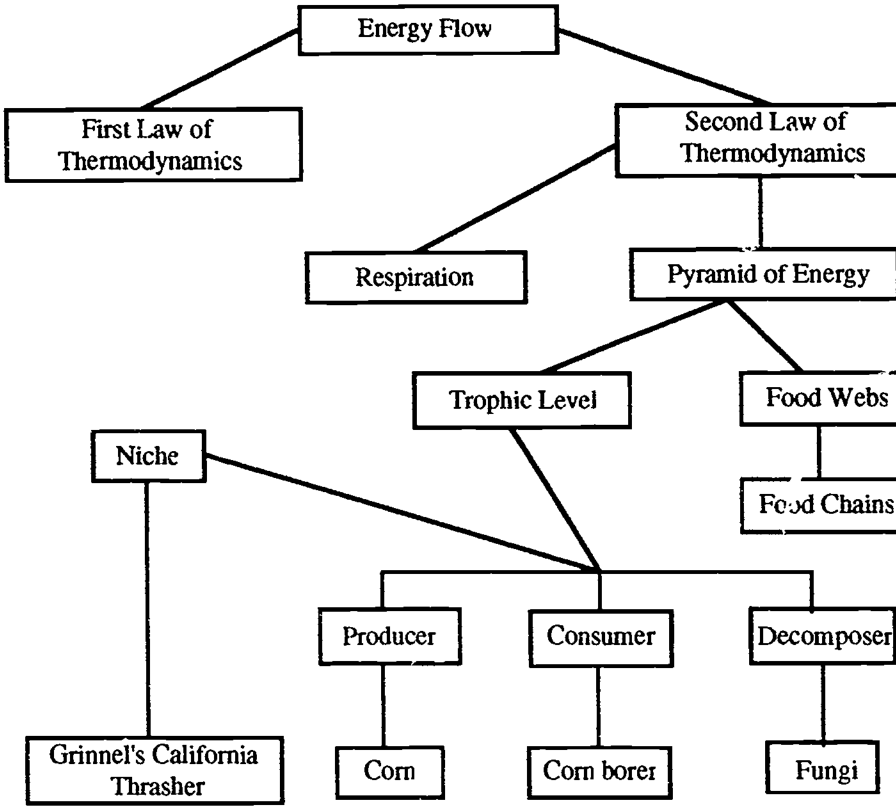

Figure 2. A general concept map for ecology (from Stewart, Van Kirk, & Rowell, 1979 in Holley and Dansereau, 1984, page 238).

Novak and Gowin (1984) draw maps by linking concepts with relations derived from the text rather than using a specific set of relations. These relations are known as propositions. (Hauf, and Novak and Gowin actually use the verb "concept mapping" for their techniques. However, as noted earlier, we propose to use "concept map" as a noun to describe a much more inclusive set of conceptual representations.)

Another technique for knowledge representation described by Holley and Dansereau is called *schematizing* involves labeling and clustering concepts and depicting relationships between concepts by lines that are annotated to reflect the seven types of relationships. The general process for schematizing is represented in **Figure 3**.

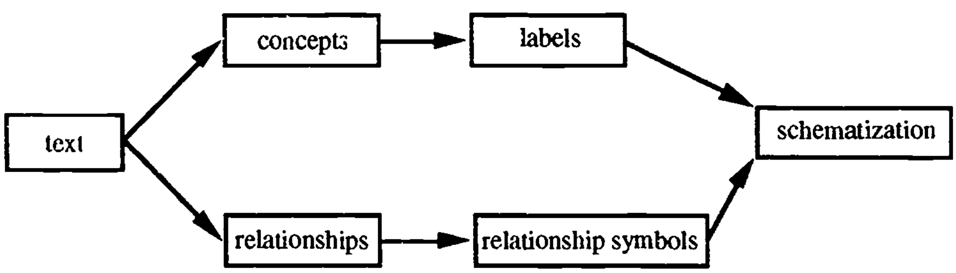

Figure 3. An example of schematization (after Holley & Dansereau, 1989).

The principal difference between networking and mapping appears to be that mapping emphasizes local organization rather than abstraction of an overall framework or schema, and that it employs spatial representations of relationships rather than labeled relationships. Schematization is similar to networking and different from mapping in that it uses annotated lines to represent relationships between concepts and it emphasizes the extraction of an overall framework or macrostructure. It is different from networking in the types of relations depicted, the method of annotation used, and the organizational structure of the resulting diagrams. The differences between these mapping strategies are superficial; they are more similar than different. We have used "mapping" in the title of this report in lieu of "networking" in order to avoid confusion with the use of electronic communication networks and professional networks.

Networking, mapping, and schematizing have been applied directly or adapted and modified to initiate various cognitive processes and achieve various learning outcomes. Concept maps help learners to extract meaning from written and oral communication. They have been used extensively to promote meaningful learning. Since curriculum development is a multi-faceted enterprise, the advantages of concept maps for curriculum development can be better appreciated if we examine the characteristics of concept maps that make suitable suitable for a variety of applications.

Applications of Concept Maps

Concept maps have been used for understanding text. The process of understanding text can be thought of as a transformation of sequences of words, sentences, and paragraphs into a coherent conceptual structure: synthesized knowledge. Carl Frederiksen (1975) presents a network model of logical and semantic structures from which speakers and writers generate linguistic messages at the discourse level. Book webbing is an extension of the use of concept maps for transforming text into spatial representations. Virginia Nordstrom and Victoria Clayton (1988) suggest the use of a form of concept maps to integrate multicultural children's literature into the curriculum. Book webbing uses children's literature to develop a study of one book; the works of a particular author or illustrator; a genre of books, such as poetry; or a topic, such as travel or magic. From the web's core based on a specific work of children's literature, the instructional possibilities of the book spin out in strands. As the plan develops, opportunities emerge to individualize instruction to meet the needs of each student's learning style and interest.

Concept maps have also been successfully used as advance organizers. Willerman and Harg (1991) conducted an experiment to determine if the use of concept maps as advance organizers improved the science achievement of eighth-grade students. They found that a concept map provided teachers with a meaningful and practical structured approach for introducing advance organizers in the class. In their study, a concept map developed by teachers was used as an advance organizer and was presented to students as a visual tool for organizing content. Willerman and Harg felt that the students were helped by the organization and visual relationships of the advance organizer in ways that are more effective than the assistance provided by a prose passage or an oral explanation. The concept map assisted the teacher in describing the relationships between important ideas and learners' knowledge.

Concept maps have been used as a guide to develop hypermedia applications. Authors need a way of representing knowledge structures so that: (a) they know the relationships between concepts and therefore do not make unwarranted leaps or linkages between them; and (b) end-users can see, at a global level, the interrelationships between concepts. If end-users can see the overall map of knowledge; then they can make informed choices about the order and sequence of learning (individualizing), and at the same time check that their sequence is coherent with more general understandings. Designers often resort to some form of mapping to analyze the content and sequence of instruction. Students in the Department of Educational Technology at San Diego State University also use a computer-based semantic network tool to map out concepts and relations in a particular knowledge domain. **Figure 4** is an example of a semantic network used to analyze content for a biochemistry laboratory course.

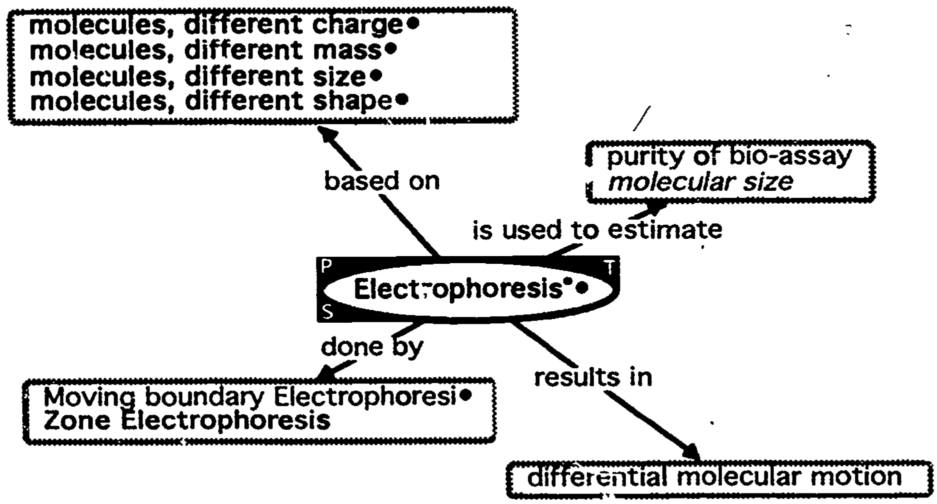

Figure 4. An example of a semantic network used to analyze content for a multimedia course on biochemistry. The display is from a SemNet file. Clicking on the *P, T,* or S tabs activates supplementary fields for pictures, text, or synonyms (from Allen & Hoffman, in press).

Cognitive Maps

Cognitive maps may be described as representations of an individual's knowledge. Learning occurs when students link new concepts into more comprehensive structures and patterns. Each learner's associative patterns are unique and it may be useful to examine them in terms of the concepts the learners emphasize, the relations that link the concepts, and the strengths of these links. One study in this area was conducted by Kathleen Fisher (1989) who analyzed biology nets built by her students and obtained insights into the students' cognitive abilities that would have been difficult with conventional assessment methodology. Comprehensive essay questions do yield some information about the students' understanding of the subject matter; however, analysis is problematical.

Cognitive maps are also an excellent tool for representing the teacher's/expert's knowledge. According to Shulman (1986), teachers need both content knowledge and pedagogical expertise. The types of content knowledge they require can be broken into three categories:

- subject-matter content knowledge;
- subject-matter pedagogical knowledge;
- curricular knowledge.

All three types of knowledge can be analyzed and synthesized using concept maps. In developing subject matter content, teachers must go beyond the facts and concepts in a domain to consider patterns that reflect the substantive and syntactic structures of knowledge. These patterns help the teacher to convey the concepts in the domain. Perhaps even more important, they help the teacher to explain why a particular concept is worth knowing and how it relates to theoretical and practical issues both within the discipline and without. In the category of subject-matter pedagogical knowledge, Shulman includes useful forms of representation such as illustrations, analogies, examples, demonstrations, etc. These can be mapped prescriptively using relational descriptors that specify causal relationships between required learning outcomes and recommended strategies. The third category, curricular knowledge, is knowledge of the full range of programs, materials, and facilities available for teaching different concepts at various levels.

Shulman's categorization of a teacher's knowledge lends itself to an explanation of our method. The characteristics of concept maps that have been exploited for other applications can be brought to bear in rationalizing the curriculum design process. Concept maps can be used to show concepts and relations explicitly for subject-matter content analysis. Pedagogical strategies can be incorporated into the concept maps. Time and task allocations can be made. On the other hand, the curriculum designers and experts can incorporate their cognitive structures also into these maps. Thus curriculum developers can create what we will call integrated curriculum knowledge maps to first input the knowledge base, then reorganize it to suit the instructional objectives and finally extract a curriculum that can be justified. These integrated maps can be successfully used by curriculum developers to organize, analyze, and synthesize the information.

Integrated Curriculum Knowledge Maps

In previous sections, we have discussed three approaches to mapping knowledge: curricular maps are concerned with knowledge as it is represented by institutions for the convenience of educational delivery systems; concept maps are concerned with knowledge as it is publicly represented by a community that specializes in a particular knowledge domain; and cognitive maps are concerned with knowledge as it is represented in the minds of individuals. There are, of course, overlaps. For example, the creation and interpretation of concept maps is obviously influenced by the unique cognitive structures of individuals who author the maps. On the other hand, the assessment or diagnoses of individual student understanding through cognitive maps can be influenced by the concept maps used to represent the "knowledge domain."

This report is concerned with another type of overlap, or rather derivation: the development of curricular maps from concept maps. Although the use of concept maps for curriculum development is not new, the representation of large amounts of information in the form of a map that is suited for navigation, perusal, and processing is a new type of software engineering problem. Knowledge representation is one the of the central issues in knowledge engineering, a rapidly advancing field that offers many techniques (including concept mapping) with potential relevance to curriculum development (for a review, see Tuthill, 1990). However, to be practical for use in curriculum development, we believe such techniques must be brought to the level of "desktop computing" i.e., usable by professional educators, administrators, and other leaders whose primary expertise is not computer programming or information processing.

Tools for computer-based curriculum development must effectively support elicitation and organization of relevant knowledge from a variety of sources including reports, books, subject-matter experts, teachers and administrators. Such tools must also support analysis of relationships between curricular elements such as competencies and learning activities and the synthesis of structures familiar to educational institutions: courses prerequisites, scheduled class sessions, etc. They need to be supportive of collaborative work, open to modification and they must have a "learning curve" that does not impose an unnecessary burden on development specialists.

Such tools have only recently become commercially available in the form of computer-based graphical mapping tools which represent complex relational data as n-dimensional networks. One example, used extensively in this study, is *SemNet* developed by the SemNet Research Group (1991). *SemNet* serves as a framework for modeling human semantic memory—described by Tulving (1972) as "a mental thesaurus, organized knowledge a person possesses about words and other verbal symbols, their meaning and referents, about relations among them, and about rules, formulas, and algorithms for the manipulation of these symbols, concepts, and relations." Although cognitive psychologists have proposed several other types of memory, semantic memory is widely seen as crucial to the acquisition, processing, and retrieval of verbal knowledge and therefore central to learning, especially in school-like settings.

Semantic memory has been known to be associative since the time of Aristotle. However, it is only in the last two decades that associative memory has taken a firm hold with those interested in modeling human memory or providing working memories for "intelligent" computer programs. Semantic networks typically organize knowledge in terms of two types of elements: concepts and relations. Concepts are not easily defined but include a wide variety of entities such as ideas, objects, notions, beliefs, events, features, properties and states. For the purposes of this project, a concept represents anything that can be assigned an identity. New concepts are defined by relating them to pre-existing concepts.

SemNet uses object-oriented programming and the Macintosh graphical interface to display labeled nodes (referred to as "concepts") and labeled arrow-links (called "relations"). Node-link-node sequences are called "instances." It can be used to represent a wide variety of domains to the extent that they can be represented as semantic networks or propositional networks. In typical browsing maneuvers, users see a central node connected to its immediate "satellites" (see **Figure 5**). Clicking on a satellite node "moves" the frame so that the satellite assumes the center position thus revealing *its* satellites. In the process, the visible label for asymmetrical links will change. For example *"formative evaluation*—ISA—> *evaluation"* becomes *"evaluation*—is a kind of—> *formative evaluation."*

Moving through a sequence of alternating nodes and links generates a "path" which can be circuitous, that is a path that entails a single node several times. (This results when the user visits the same concept repeatedly.) Users can also move quickly and intuitively through large nets by selecting items in indexes, or by invoking utility commands such as "jump" and "replay path."

Easily-used commands afford several techniques for creating and modifying connections; experienced users can construct nets at rates exceeding several instances per minute *if* they are clear about how to organize their ideas. Users can assign graphics and short text passages to nodes and links (and in future versions will be able to assign video and audio segments to nodes). They can also export graphics and ASCII text representing indexes or net contents and subsets thereof.

The program provides a variety of metrics about the size and complexity of a net and uses these to assemble various types of summaries and overviews. Almost anyone who browses through a SemNet expresses interest in viewing "the whole net." This has proven problematical since SemNets are n-dimensional structures that cannot easily be visualized in two dimensions. But the problem has been addressed by special displays.

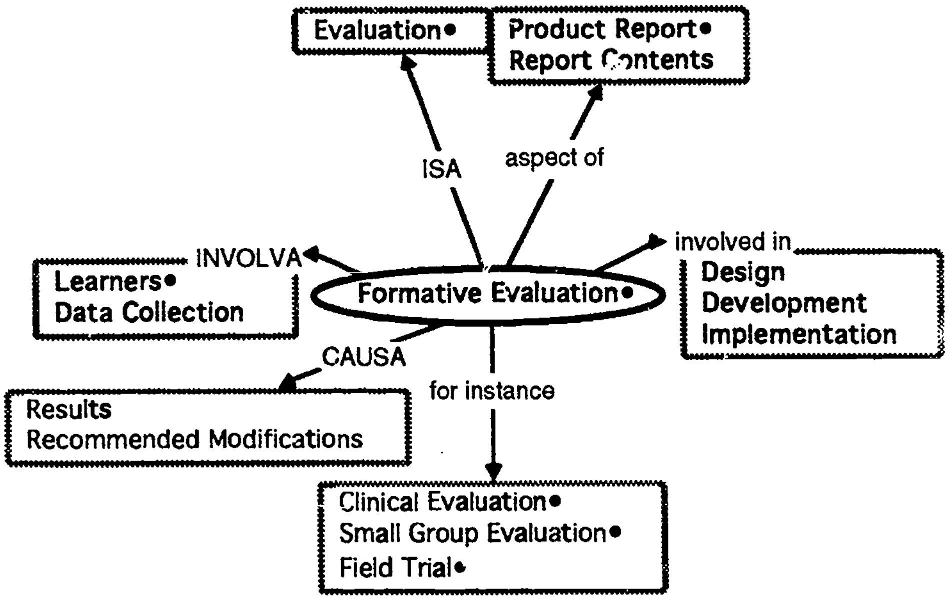

Figure 5. Concept map from a course on instructional design (from Allen & Hoffman, in press).

For example, measures of the "embeddedness" of concepts are used to generate a "knowledge core" in which the most embedded nodes are laid out in rows and connected by crisscrossed lines (**see Figure 6**). Other utilities let users see the shortest path between two nodes, or traverse the net viewing only node-and-satellite frames that meet user-established criteria.

Because *SemNet* uses a flexible, multi-dimensional graphic mapping strategy, it can be used for integrated representations of curricular maps, concept maps, and cognitive maps, and it can be used to derive structures in one map from structures in another. The experiments described here focus on deriving curriculum maps from concept maps. It is also possible to use *SemNet* to explore relationships between concept maps and curriculum maps one hand and individual cognitive maps on the other, but this is a subject for another report.

Development of an Integrated Curriculum Knowledge Map

To explore the possibilities of integrated curriculum mapping, a team of students drawn primarily from the SDSU-Claremont Graduate School Joint Doctoral Program in Multi-Cultural Education assembled under the direction of Dr. Brock Allen at San Diego State University. The framework for their efforts was provided by Dr. Thomas Sticht, President of Applied Behavioral and Cognitive Sciences. Dr. Sticht is developing a design for a model degree in Workforce Education and Life-long Learning.

The proposed WELL degree program will be aimed at producing educators capable of delivering basic knowledge and skills required for the workplace of the future. WELL Specialists are to organize and implement programs for the educationally underserved. This population includes high school dropouts, those with inadequate literacy skills for acquiring or maintaining a job, or those with jobs who are immobilized by the lack of such skills.

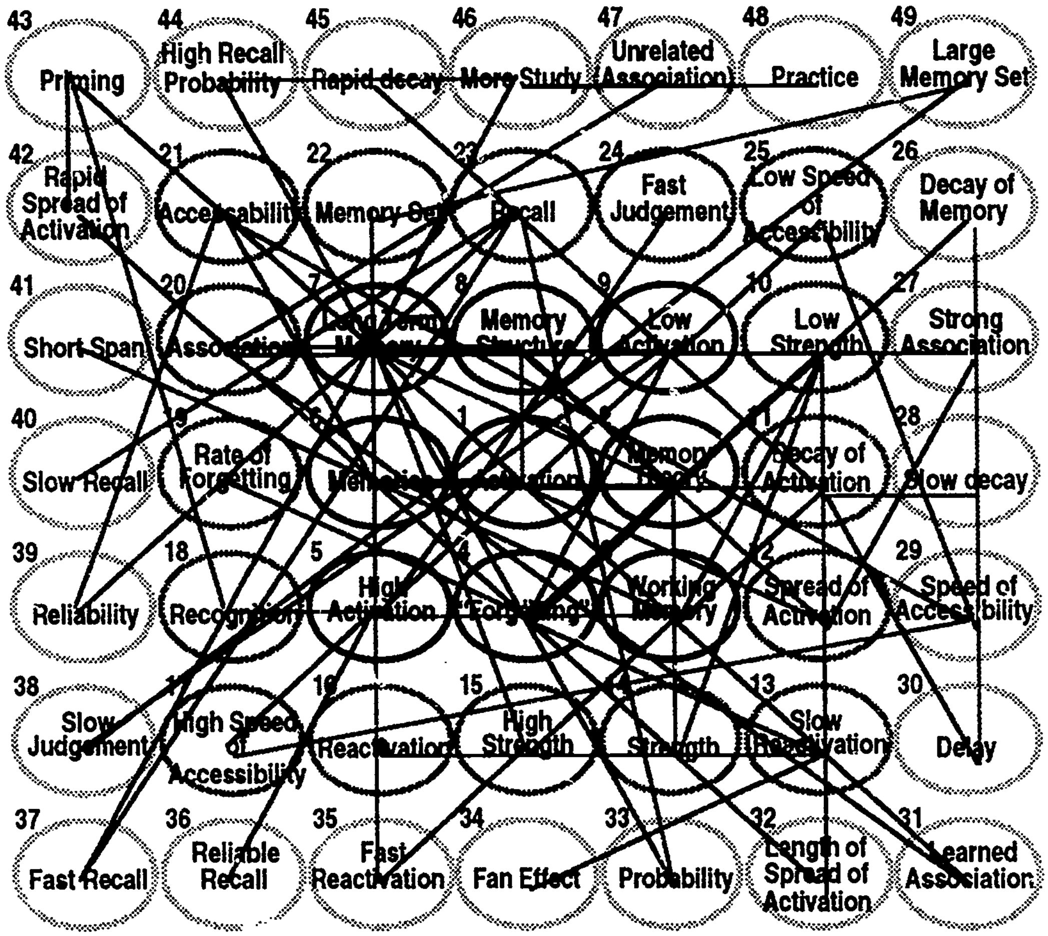

Figure 6. "Knowledge core" from a concept map used in a course on instructional psychology (from Allen & Hoffman, in press). Some labels have been truncated.

The SDSU team first met in early September, 1991, with ten participants[2]. Their occupations ranged from teaching and counseling to instructional design. Areas of interest included administration and philosophy of science. Ethnic origin embraced the Pacific Islands, Mexican, Asian, African, and European heritage.

The team's primary goal was to demonstrate the use of computer-based mapping as an aid to curriculum development. They wanted to explore whether *SemNet* could serve as a means for assembling and organizing an integrated curriculum knowledge map encompassing potential competencies, course structures, and corresponding learning activities. A second goal was to develop a set of protocols and procedures for collaborative net building. A third goal was to lay the foundations of a database that would include competencies, course structures, and learning activities for the model WELL Specialist masters degree program.

A goal that emerged later in the semester was to demonstrate techniques for using *SemNet* to aid in the organization of courses and other high-level decision

2 In addition to the authors, these were Alejandro Benitez, Thomas Gaffney, Caroline Huey, Rebecca Kvederis, Robert Reeves, Velma Sablan-Martinez, Linda Swanson, and Derry-Joe Yakubu.

processes by identifying patterns in the raw data, unencumbered by categorization imposed by data sources.

An experimental process was adopted to accomplish the team's goals. This process was modified and refined during the course of the project, and from the team's experience we have extracted an idealized six-step model (**Figure 7**).

Process Description

The project began with a review of the social and political impetus for the model program, along with pertinent research. Three sub-committees were established to catalog descriptions of the knowledge WELL Specialists would need, focusing in three areas: cognitive foundations of education, educational arts and technologies, and human and cultural resources. Each sub-committee used *SemNet* to enter knowledge descriptors into a domain-specific subnet.

The three subnets were then combined so the entire team could collaborate to edit the main net and explore strategies for generating useful information from the net. Divergent terminology in both knowledge descriptions and the relations that are used to link them were reconciled as the subnets were combined into the main net. Merging was accomplished by manually reentering the subnets into a main net. More efficient merging capabilities have since been added to the *SemNet* program.

A Macintosh computer lab with an LCD overhead projector enabled team members to work together and to share nets and net-building techniques. *Timbuktu* (Killen et al, 1990) software allowed multiple users to control the activity of a single host computer. Outside the lab, traditional methods of file sharing, namely, floppy disk swapping and exchanging files via modem, were utilized.

1. Gather Relevant Descriptions of Knowledge

In the first step, subcommittees used *SemNet* to catalog knowledge descriptors gleaned from a variety of sources including reports, textbooks, subject matter experts, and existing course syllabi. For the purposes of this study we define a knowledge descriptor as a label for a concept or skill (or sets thereof) which may be of value to WELL Specialists in their professional practice.

2. Construct Hierarchical Links between Knowledge Descriptors

In the second step, hierarchical relations were used to represent the topical structures of the various source documents. This permitted efficient input of typically hierarchical sources such as reports, textbooks and course syllabi. It also enabled later extraction of the hierarchical structures in outline form using a *SemNet* hierarchical outline utility.

Hierarchical structures were entered prior to heterarchical ones when representing a given document. Consensus for this strategy emerged from divergent approaches taken by different subcommittees. One committee entered hierarchical and heterarchical relations concurrently. An instance entered with a heterarchical relation was not necessarily entered again with a hierarchical relation. This precluded later extraction of the entire document outline using hierarchical relations.

A second committee its work by cataloging knowledge descriptors from course syllabi, using only hierarchical relations at first. Later they used heterarchical relations to "cross-link" the knowledge the knowledge descriptors. The hierarchical structure reflected in the original source documents thereby remained intact and could be extracted even after extensive heterarchical cross-linking (**Figure 8**).

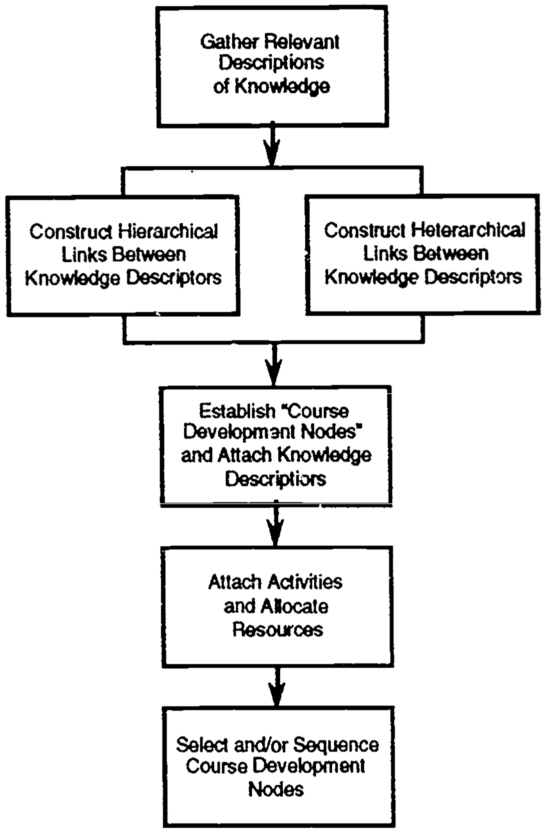

Figure 7. An idealized six-step model for using a computer-based semantic network program to construct an integrated curriculum maps.

3. Construct Heterarchical Links between Knowledge Descriptors

The third step employed heterarchical relations, such as causal and procedural relationships, to cross-link the knowledge descriptors within and among documents (**Figure 9**). This step was carried out initially in the subnets and then again after the nets were merged into the main net.

The strategy for interconnecting nodes is one way to counteract the effect of top-down bias stemming from prior categorization imposed by the original authors of the descriptions of knowledge. The various syllabi, documents, and material from subject matter experts all came framed in their own categorical structures. The interconnect process was designed so that, hopefully, natural centers of gravity would emerge from the mass of knowledge descriptors in the main net itself, rather than from these prior categorical structures. To accomplish this, the teams first attended to those concepts that were *least* embedded or linked to other concepts in the net. It was assumed that later, once these simple units had been linked into compound structures, new patterns might become evident.

SemNet screens list concepts by the number of branches, by embeddedness, and in alphabetical order. Studying the list of concepts arranged in order of the number of branches or links to other concepts can help the curriculum developer get

educational technology
edtec 700 cogn. & inst. design
edtec 700 cogn. inst. topics
cultural differences

meaning-based knowl.
represent.
scientific problem
solving
designing transfer of
expertise
perception
perception-based knowl.
repres.
elaboration and
interference
memory processes
sematic networks
neural basis of cognition
thinking and reasoning
military training
prog. . .
sem. soc found. of education
social influences of education
political influen. of ed. proc.
educational reform
tenure
teacher competency testing

Figure 8. The first portion of an outline generated by *SemNet* beginning on the node "Educational Technology" and based on the relation "has topic." Although many of these nodes have been extensively cross-linked to other parts of the net, the hierarchical structures of the original course syllabi have been extracted by isolating concepts linked by the "has topic" relationship. Limitations on the size of labels for concepts in *SemNet* necessitated abbreviation of knowledge descriptors.

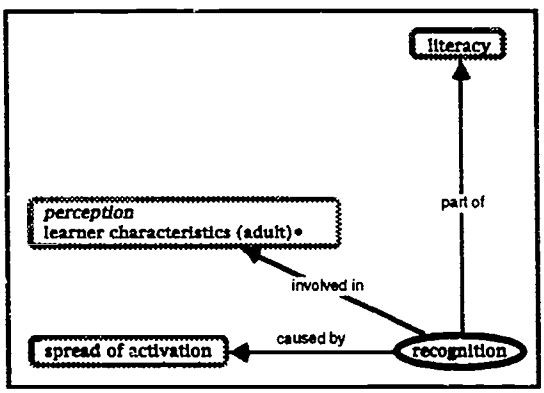

Figure 9. An example of a moderately-connected or "compound" concept. "Recognition" is linked in a variety of ways to other nodes within the curriculum net.

a sense of what might be the more important concepts (**Figure 10**). If a concept is important, or central, to a domain, it is presumed to have many direct connections to other concepts.

Listing concepts in order of embeddedness offers further evidence of centrality or importance. For example, if a concept has three related concepts, but each of those three concepts average, say, three related concepts each, then the original concept is said to have an embeddedness of 3 x 3 + 3 = 12.

Lists of concepts in creation and alphabetical orders were used more as net editing tools than as analytical tools. Creation order enabled later identification of separate documents represented within the net. Team members inserted marker nodes between documents to help in later distinguishing the sources of various competencies. Alphabetical order helped search for specific competencies during the cross-linking process.

Concepts by Number of Instances		**1238 items**
46	WELL Specialist	116
31	SDSU Learning Activities	87
27	literacy	179
26	Literacy Delivery System	136
21	problem solving	140
19	multicultural paradigm	79
19	administration	108
18	cognition	128
17	action research	146
16	thinking and reasoning	130
16	te 423 instructional topics	44
15	edtec 700 cogn. inst. topics	72
15	perception	83
15	restructuring	72
1	learning environment	12
1	content expertise	12
1	basic education (non-school)	2
1	Labor's Perception	8
1	articulate educative needs	10
1	inferential study	11
1	bottom-up processing	3
1	equipment	4
1	success	12
1	tools for representation	3
1	speaking	12

Figure 10. The beginning and end portions of the list of concepts in order of the number of branches or instances. The heading indicates that the net consists of 1248 items or nodes. The number to the left of each line of the list is the number of direct links or branches between the listed node and other nodes in the net. The number to the right indicates "embeddedness," which adds to the number of direct branches the number of the branches' branches.

Cross-linking of the subnets was carried out within subcommittees using a single computer and the print-outs described above. After merging the subnets, a somewhat different strategy was employed to cross-link within the main net. This took place in the computer lab, where each subcommittee had access to two or three computers. One computer in each subcommittee provided access to the master net through *Timbuktu* (Killen et al, 1990). Since only one computer could actually control the master net at any given time, a token was rotated among the subcommittees so that all would know where on-line editing activity was taking place.

The token was passed between subcommittees about every ten minutes or at a natural break in activity. During the twenty minutes or so when the token was elsewhere, each subcommittee identified those nodes in their net that could be linked to other concepts in the master net. To aid in identifying potential links, a second computer in each subcommittee contained an off-line copy of the master net as a reference and a third computer contained a reference copy of the subcommittee's subnet. The subcommittees also used various printed lists of concepts derived by using using SemNet's "traverse" utility.

Typically, while a subcommittee was "off-line," its members worked with a list of concepts arranged in order of the number of branches. They worked from the bottom of the list, beginning with the least-connected concepts. Taking each in turn, they scanned the alphabetized list of concepts from the master net to identify several possible links. For example, the concept "school restructuring" seemed to be related to the concepts "educational reform" and "organizational change" that had been entered by other subcommittees.

In order to check the meaning of all three concepts, the subcommittee "jumped" to each in turn on the off-line copy of the master net. They discovered that, indeed, the concept "restructuring" appeared to be related to the more inclusive concept "educational reform," based on the contextual links of the latter. A note was made to link them. However, the concept "organizational change," seemed to have a very specific context having to do with workplace issues, and a link was thought inappropriate. As other concepts were found to have important or interesting connections in the master net, the subcommittee kept notes until the token arrived. They then took control of the on-line master net and entered their changes. Concept by concept, the ideas became gradually more interrelated and embedded in the master net. On occasion there was doubt concerning the existence or meaning of a concept and the subcommittees would instigate oral communications in an effort to clarify or resolve differences.

After linking these simple concepts from the three original subnets into meaningful clusters or "compound concepts," the subcommittees turned to making links between the compound concepts. (Many of these had been formed earlier during development of the separate subnets.) Linking compound concepts produced highly embedded nodes that seemed to function as centers of "conceptual gravity" (**Figure 11**). The process of linking compound level nodes was conducted in the same fashion as that for linking simple nodes.

It should be noted that the student participants in this process were not subject matter experts in adult education or educational psychology and therefore the representations in Figures 11 and 12 are perhaps a bit naive. Our concern in this study was primarily with the process of curriculum development rather than content per se.

4. Establish "Course Development Nodes" and Attach Highly Embedded Nodes

In this step, teams developed structures for potential courses in the masters degree program. Of some 1,200 concepts, the master net yielded 48 with ten or more direct links to other concepts. Examination of the 48 nodes revealed that many could be thought of as central concepts in a master's degree program. Although time was

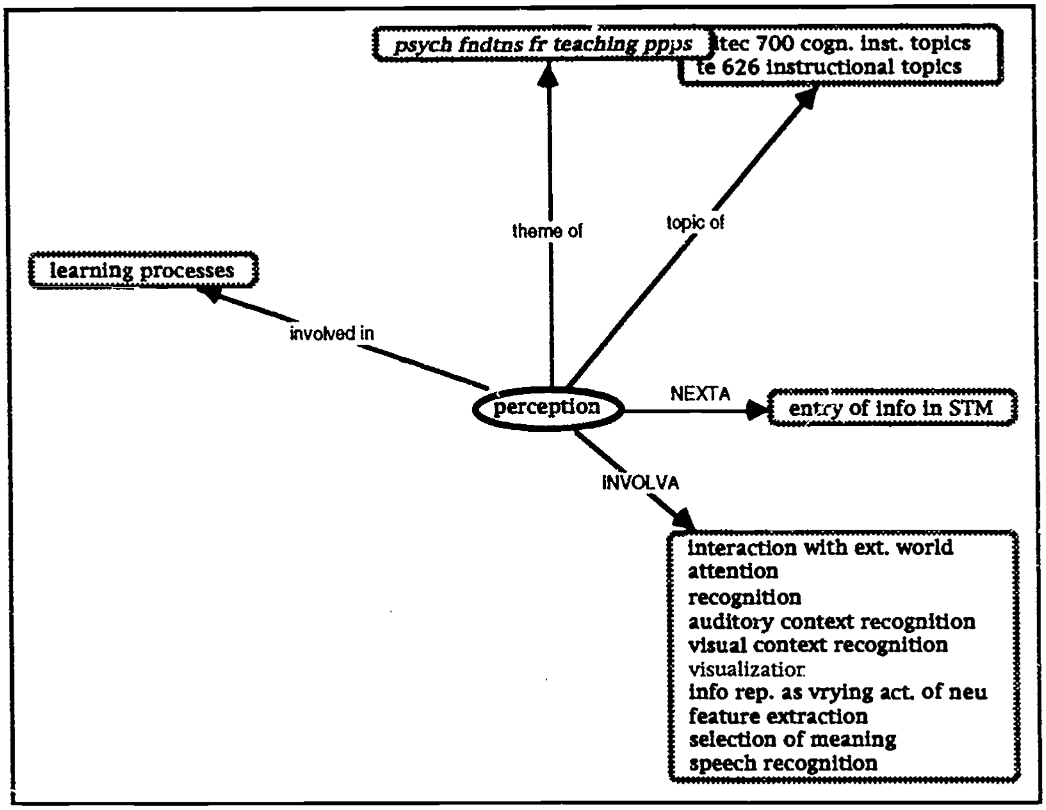

Figure 11. An example of a highly embedded node. "Perception" is connected to a number of other nodes with a variety of relations. Those nodes listed in bold type have additional connections to other nodes, which may be displayed by double-clicking on them. The number of branches from "perception" would identify it as a potentially important concept for subsumption under a "course" node.

limited, the team experimented with creating a three-unit course and in less than an hour of discussion, they identified nearly a dozen thematic concepts that could be subsumed under a node they called "foundations of psychological development," (**Figure 12**) including such themes as "perception" and "cognitive development." This subsumption node was suggested as a tentative basis for a course or series of courses within the proposed degree program. This node was developed in a period of three hours by students without extensive expertise in psychology. Therefore it is illustrative of the course development process and cannot be considered as a recommendation for actual course content. However, it could serve as a rough framework for further discussion with content experts.

5. Attach Activities and Allocate Resources

The next step was to link various course themes to a battery of suggested learning activities. For example, a theme dealing with visual phenomenon might rely on textbooks, demonstrations, computer aided instruction, and laboratory activities. By identifying trends in learning activities that might be appropriate to the mix of subject matter projected for the program, allocation of facilities and resources would be facilitated.

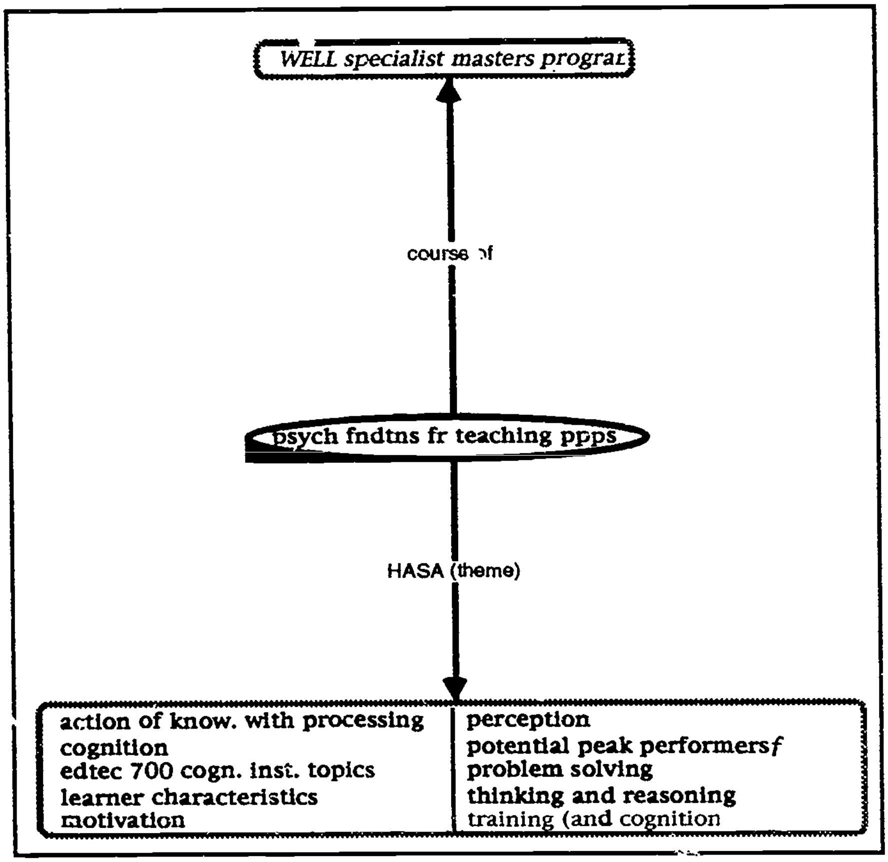

Figure 12. Psychological foundations for teaching "potential peak performers" was established as a subsumption node and then linked to a number of themes, including "perception" (see **Figure 11**).

6. Select and/or Sequence Course Development Nodes

A number of proposals for using the main net were generated. In addition to course and syllabus compilation and resource allocation, both mentioned above, the net could be used by counselors and students to develop an individualized course of study. It could also be used to help prospective students make course selection decisions.

Using the Integrated Curriculum Knowledge Map: A Scenario

With the completion of the six-step process, the main net could be considered by our definition to be an integrated curriculum knowledge map since it incorporated structures that represented concept mapping (clusters of knowledge descriptors) as well as curriculum mapping (a course and clusters of course activities). To further explore the implications of the integrated map as a framework for the proposed WELL program, each of the team members worked with us to construct a scenario that addressed some practical problem in course development or individualized learning. Included here, in edited form, is one of these scenarios; it should be considered tentative and exploratory.

Rebbeca Kvederis, who directs career counseling services at Palomar Community College in California, describes how the integrated curriculum knowledge map could be used to counsel prospective WELL Specialists on the suitability of the master's degree program for their needs, capabilities, and interests.

She also examines the possibilities that the map offers for guiding individualized study plans.

Using Integrated Curriculum Knowledge Maps in Academic Counseling
Developed with Rebecca Kvederis

The essence of all counseling relationships, whether focused on personal, academic, or career issues, is to help the client "cope effectively with an important problem or concern, to develop plans and make important decisions to bring about a desired future, to acquire information about self and relevant aspects of the environment, and to explore and consider options available" (Eisenberg & Delaney, 1977, p. 3). College academic counseling is a process in which an academic counselor assists a student, or prospective student, in planning a program of studies. Counseling involves consideration of the current skills of the student (through portfolio review, assessment test scores, etc.), the interests of the student in terms of career and major goals, and the selection of courses from among those available to meet degree requirements.

Academic counseling is rarely a one-time event. College students request counseling as a means of gaining preliminary information about the options available to them prior to engaging in educational planning. Thus, the initial stage in this interaction is exploration and information gathering, leading eventually to the development of an educational plan. A plan may be retained or it may be rejected, often several plans are "tried on for size" before one is committed to.

Once an educational plan is written by the counselor and accepted by the student, it is implemented. Implementation of the plan (embarking on the course of study) leads to new experiences and interests that may result in further revision of the plan.

If the educational plan is a dynamic process, so is the counseling interaction that produces it. The counselor describes the requirements and the various options to the student and gauges the individual's interest based on verbal (and non-verbal) responses. Certain patterns and tendencies are noted in terms of the student's interests. These interest patterns influence the suggestions made by the counselor to the student regarding course selection.

The process of academic counseling and educational planning is limited by the available counseling tools, all of which are sequential and linear: catalogs, evaluation forms, and checklists of requirements. These encourage students to be passive in the counseling interaction since they establish an expectation that an authoritative list of requirements will be "given" to the student by the counselor, with little input from the recipient. A tool that moves away from the traditional, sequential presentation of information and incorporates the features of hypermedia would not only offer a more accurate representation of reality but would facilitate this dynamic process. *SemNet* is such a tool.

SemNet facilitates representation of various educational domains. Nodes represents clusters of skill or competencies. "Subsumption nodes" can be used to collect these nodes into traditional course structures and to assign learning activities to such structures. *SemNet* affords flexible representations curricular options. By "traversing" the net, the counselor and student can see and then select the courses or learning activities that would facilitate development of the needed competencies.

Using *SemNet* in counseling has other potential benefits. A student who is more actively involved in the educational planning process, who is taught to use the net to explore other options on his/her own, is more likely to see him/herself as responsible for and capable of planning an educational program. Also, the net may function as a sort of job aid for the counselor, cueing them to mention specific details related to the node under consideration.

The following is a hypothetical case study constructed to show how SemNet would be used in an academic counseling interaction with the goal of designing a course of study for a graduate student entering the proposed Workforce, Education, and Life-Long Learning Specialist masters degree program.

The WELL academic counselor is meeting with José Luna, a third-grade teacher for the past fifteen years in the San Marcos School District. Mr. Luna desires a new professional challenge and wants to work with adults. He believes that his bilingual skills will make him especially valuable as an instructor in the district's adult education program. His goal is to become a program supervisor and he is especially interested in a position that would allow him to continue a small research project he began several years ago which looks at parental attitudes and the connection to children's learning successes among the Hispanic population. His research ideas stem from the theoretical concepts he learned as an undergraduate psychology major and Mexican-American Studies minor.

The initial appointment is scheduled to begin the dialogue between counselor and client and to discuss available opportunities. The counselor and client would view the WELL Specialist net together, using the "traverse" function—beginning with some of the basic knowledge domains and moving from the general to the more specific. Of the 60 most embedded nodes in the WELL integrated curriculum map, Luna will select 33 that are most closely related to his goals.

As a node representing a skill or knowledge descriptor is discussed in terms of Mr. Luna's existing skills and professional objectives, an accompanying text field would display the "market demand indicators grid" that is consulted to determine the importance of the particular knowledge description to the various WELL Specialist employment settings (See **Figure 13**).

The grid would indicate the importance of the knowledge—rated on a five-point scale—to three major employment settings: schools, corporations, and agencies. The scores would represent ratings by employers and previous graduates of the importance of the particular skill/knowledge to current jobs. This information would be updated biannually and will be based on questionnaires distributed to WELL graduates and their employers. The nodes of interest to Mr. Luna would be those with a "market demand indicators grid" score of greater than three for "school settings." These are flagged for future reference. After this process is exhausted, the "complete net grid" showing all flagged nodes and their interconnections would be viewed.

This initial academic counseling session would conclude with the scheduling of a follow-up session. Mr. Luna will be given a diskette containing the WELL Specialist net and instructed on how to use it at the program's computer lab so that he may work with the net independently to explore the possible options.

In the second session, the counselor and Mr. Luna would discuss the result of his work with the WELL Specialist net. A set of desired competencies will be identified, designed to balance his interests and the needs of the job market. The next step would be to view the options for "learning activities" that are attached to the selected nodes. These activities would include lecture, independent study options, and internship experiences. Mr. Luna selects a pattern of competencies that are subsumed within several three-unit courses: *Psychological Foundations, Sociological Foundations, Research Methods and Instructional Tools and Techniques.* These courses will be included in Mr. Luna's initial educational plan.

A perusal of the market demand indicator grid for the school settings suggests that knowledge of "organizational improvement" is important competency—in the opinion of employers and graduates. Mr. Luna and the counselor agree that

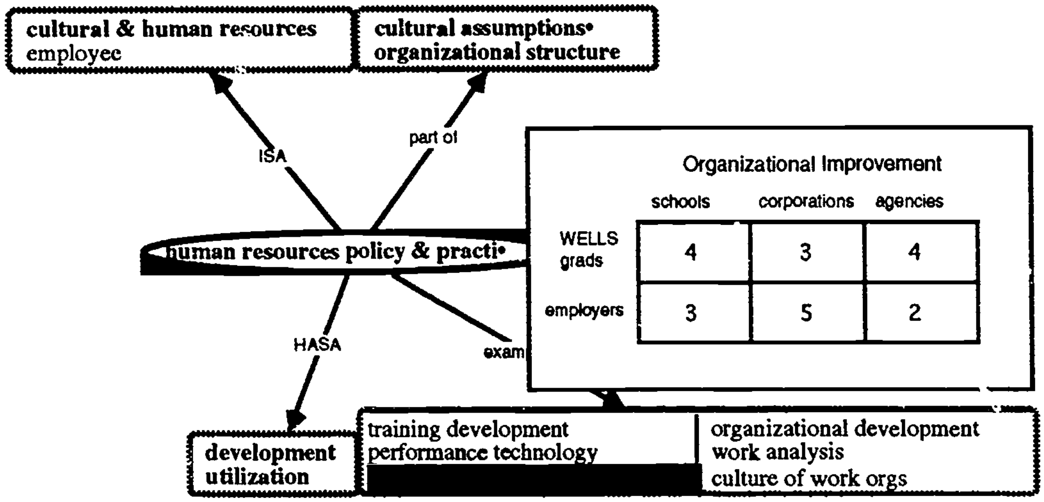

Figure 13. "Market Demand Indicator Grids" accessible through selected "knowledge descriptor" nodes would provide estimates of the importance of a particular knowledge or skill element in three types of work settings. Ratings displayed are for "organizational improvement" and would be based on surveys of employers and graduates.

the independent study module represented in the map is a desirable means of acquiring this competency. In addition, Mr. Luna indicates an interest in pursuing an independent research project stemming from his earlier work with parental influence on Hispanic children's learning successes. He and the counselor decide that an action-oriented research apprenticeship, coordinated with a faculty member involved in this area of research, would meet this need.

At the close of the session, a list of courses and learning activities would be drawn up, providing Mr. Luna with an initial educational plan. He will be then encouraged to consult the WELL Specialist net again and to initiate a follow-up counseling session, with the understanding that as he begins to implement his plan, his new experiences and interests will possibly lead to revisions. His experience in using the WELL Specialist net and his access to information regarding the available competencies, learning activities, and market demand indicators will make him an active partner in this dynamic process of academic advising.

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