TOWARDS AN INTELLIGENT TUTORING SYSTEM WITH APPLICATION TO SEXUALLY TRANSMITTED DISEASES

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7.1 INTRODUCTION

Sexually Transmitted Diseases (STDs) and especially the threat of AIDS is widely recognized as an important educational problem, particularly in the college age population. To date, intelligent software has not been developed and employed to effectively disseminate the critical knowledge relevant to this epidemic. Since STDs as a group are a personal problem which few people feel comfortable discussing, we believe the computer can provide an opportunity for learning about these diseases while insuring anonymity. This paper describes the preliminary steps we have taken to begin the development of an STD intelligent tutoring system (STD/TTS) for college age students.

The principle focus of our research is in the areas of knowledge acquisition, knowledge representation, learning, and problem solving with respect to the identification, control, and treatment of STDs. Fundamental issues which we address are: (1) the effective extraction, representation, and modification of expert/novice medical knowledge, (2) the design of an effective computer-based information system for STDs, and (3) the acquisition of problem solving techniques used by novice learners to apply this knowledge base within the context of real world needs.

This paper describes our work with domain experts using concept maps and group interviews to construct the STD knowledge base, the development, within Apple's HyperCard application, of an STD SmartBook, undergraduate nursing students' use of the STD SmariBook and finally implications for the construction of an STD intelligent tutoring system.

7.2 PRIOR WORK

Considerable effort has been expended towards study in the area of cognitive skills their acquisition, and their modelling with such systems as GPS (Newell& Simon 1972) HAM (Anderson & Bower, 1973), and ACT (Anderson. 1976), but the principle problems which still remain are (a) what is knowledge (advice), (b) how should it be represented, (c) how can it be effectively be extracted and represented for novice learners?

Anderson (1982) concluded that there are essentially three areas of skill/knowledge acquisition: encoding, (as production rules) proceduralization (whereby

facts in a declarative form are reorganized into procedures through experience), and composition (whereby individual rules are collapsed into a single rule that combines their effects). Furthermore, the knowledge associated with such skill acquisition tends not to be constructed in a formal top-down manner Experts seem to be able to perform cognitive leaps based upon acquired know-how or intuition. However, it is also accepted that experts tend to be poor in articulating precisely just how they are able to solve difficult problems within their domains of expertise.

7.3 CONCEPT MAPS AS KNOWLEDGE REPRESENTATION

Research in knowledge representation has come from three distinct fields: AI, linguistics, and cognitive psychology. Work in linguistics provides us with the basic premise that knowledge can be reduced to a relatively small set of relations between concepts. Work in AI, based on a cognitive psychological perspective, provides us with techniques for knowledge representation. One such approach is to combine small subsets of knowledge into larger networks connected by relations, i.e., semantic networks. Quite a few researchers in cognitive science have adopted these methods to help illustrate thinking and learning.

In this study we utilize a graphical knowledge representation methodology called concept mapping which has been successfully applied to a variety of formal classroom learning situations (Novak and Gowin, 1984) and informal adult education (Brody. 1985). Concept Mapping has previously been somewhat independent of the AI domain intended here for its application. However, its roots in cognitive psychology and learning suggest its suitability for our investigations. In addition, we know of at least one other ongoing research effort which is based on this form of knowledge representation (Feifer, Dyer, and Baker, 1988; Feifer, this volume). Concept mapping provides a framework for representing subject/expert/novice knowledge. It is based on the assumption that we think with concepts and that these ideas are linked together in meaningful idiosyncratic relationships by the learner. Large numbers of concepts and their relations are joined together into a major conceptual framework or schema. Concept maps of small numbers of concepts can then be joined together forming complex semantic networks representing schema (Collins and Loftus.1975). In this study concept maps were used to help extract expert and novice knowledge, identify key concepts involved in STDs, and represent them in easily understandable formats for both future teaching and learning in a computer-based intelligent tutoring system. University of Maine Health Center medical doctors and health educators collaborated on the construction of concept maps for six STDs during group interviews. The resulting maps help make clear the relatively small number of concepts and relations that need to be focused upon in learning about STDs. Fig. 7.1 is a concept map of the major subsuming concepts in an extensive network of maps related to STDs.

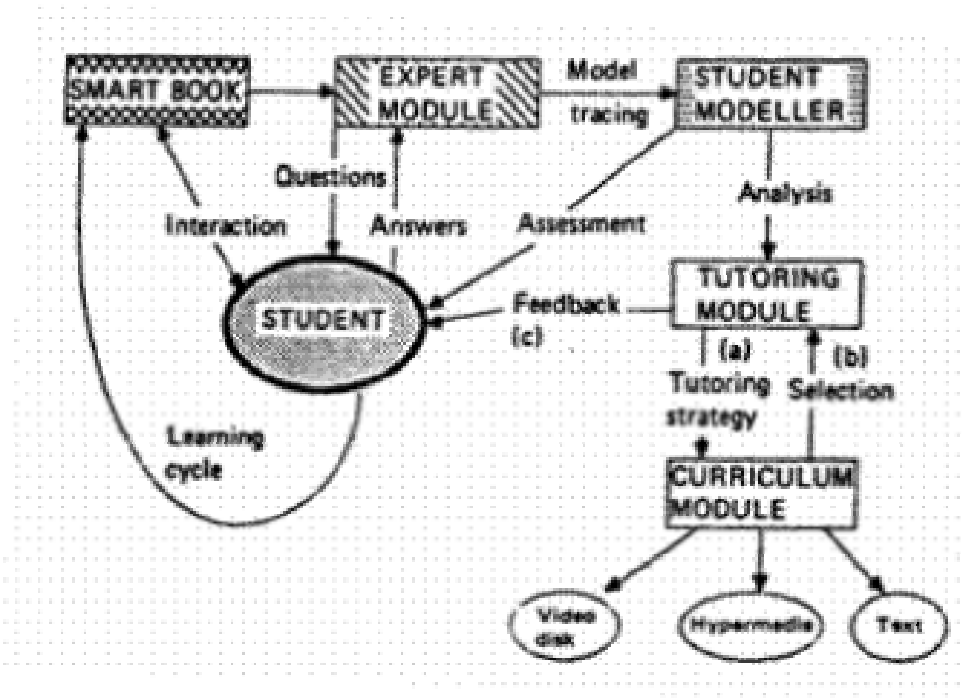This stack contains all concepts related to STDs

Fig. 7.1 – The major concepts of STDs.

Concept maps were constructed for six STDs by the campus health care experts and collectively represent their understanding of the infectious diseases (see Fig. 7.2). A number of critical concepts; signs symptoms, prevention, treatment, host, and transmission provide a pervading skeletal and hierarchical structure for each disease. This forms the basis of a semantic network knowledge base from which we are constructing the intelligent tutoring system's expert and student model components.
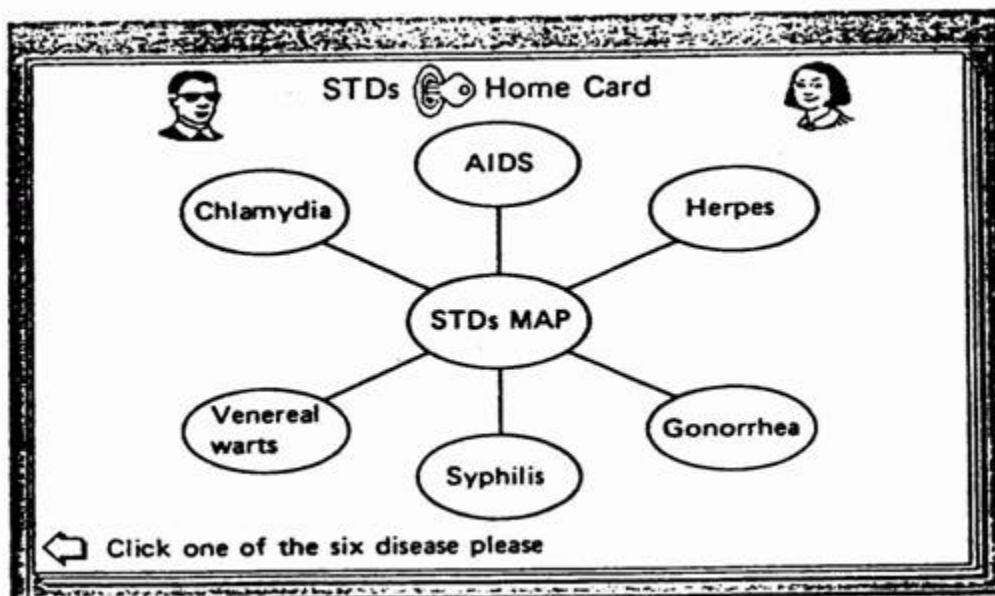
Fig. 7.2 – STDs for which concept maps have been constructed.

7.4 The SMARTBOOK

The issues of knowledge representation and knowledge acquisition are fundamental to the study of artificial intelligence and intelligent tutoring. Most people would probably agree that much formal learning relies on books consisting of words which comprise textual information or photos which comprise graphical information. A well-written and well-structured book can be considered an excellent source of information on a subject and integral to a student's learning. Books tend to be complete and sequential in their presentation of material. There is also an implicit hierarchical structure for the knowledge in most books which attempt to present learning material. This structure emails the presentation of material in a linear and top-down form. That is, the general overview of a subject is presented first and then details on specific relevant topics or methods will follow. Each topic is presented in an order prescribed by the author. A good text will have all the important subject information as well as a table of contents and index detailed enough to direct the reader to information on a topic of interest which is covered in the book. Key words may also be highlighted in some way.

However, traditional books lack flexibility in the order of presentation of information and will lend to omit the most important relationships between concepts presented in various pans of the book. This is due to the very static nature of this form of knowledge representation, the style and content being rigid and unchangeable once a book has been published.

The primary advantage of our SmarlBook is flexibility and the opportunity for the learner to explore relationships between concepts. That is, it can be used in many ways and important links between concepts are included in the presentation. The order in which material 10 be learned is presented is the choice of the user. In essence, the SmarlBook, as coined by Feigenbaum (1988). represents a road map through the knowledge base of STDs.
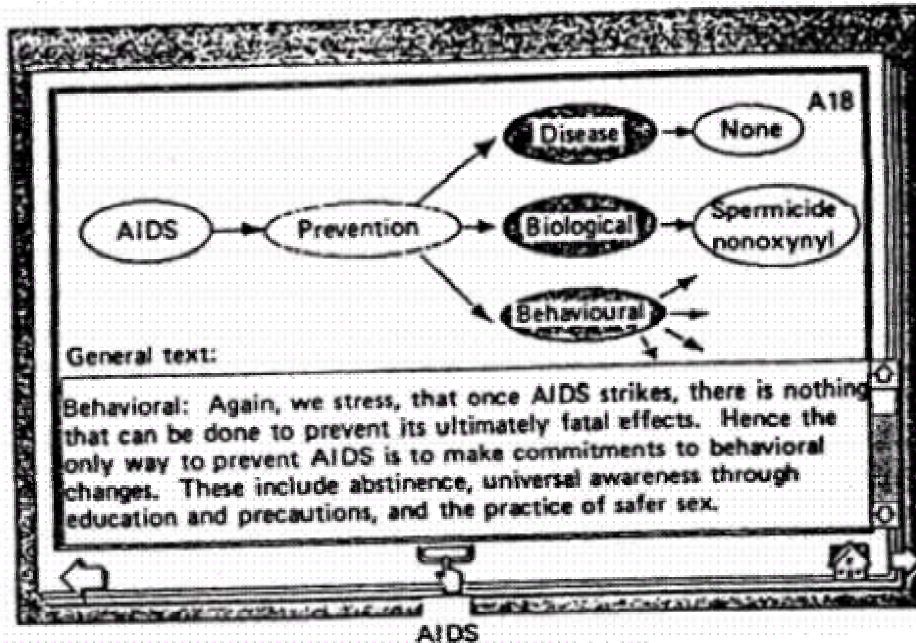
Fig 7.3 -- AIDS SmartBook sample card.

Information in the SmartBook is represented in two forms: graphically and textually (see Fig. 7.3). Graphical information has been derived from a form of knowledge representation called *concept maps*. The structure of these maps can embellish the knowledge of experts in a domain. Typically any node on a screen can be "clicked" to proceed to the next screen with a new map segment and more information. The key to a SmartBook's flexibility is that one can move in many directions via the nodes and arcs in a graph. Concepts in nodes are connected by arcs. Importantly, at all times the user can quickly determine how the current node was reached and what the possibilities are for proceeding from the current node. Textual information is always presented in a brief, compact and clear form. The same is true for graphical information. The graphs on a card have deliberately been kept simple, hiding the complex connections which may comprise the concept map of the domain being represented. As an alternative to overloading the user with too much information in a particular card (or screen), we have left the edges with arrowheads (but no nodes attached) intact, representing topics which are further developed on subsequent cards.

The system has been developed in HyperCard, the Macintosh hypermedia system, which enables the user to interact with many forms of information. Transparency in form and function is fundamental to the SmartBook. In addition to existing pop up windows and a glossary of terms, there is the potential for linking to synonyms for key words, a retrace facility, expert advice, and video-disk presentation of graphical information. As any good knowledge base, it is easy to modify, expand, and refine. The SmartBook is viewed as an important stepping stone to ultimate goal of building the STD/TTS.

7.4.1 SmartBook unification

Our prototype AIDS SmartBook has undergone considerable evaluation and revision before its completion and installation on a public computer cluster for use as an educational tool. This has been primarily due to: (1) our inexperience in developing SmartBooks and (2) the dynamic nature of the AIDS concept map as a consequence of changes in the AIDS knowledge base. Nonetheless, as a result of consultations with professionals in science education, educational
technology, health education, psychology, and computer science, we believe the formal, style and content of our SmartBooks to be scientifically and educationally sound. The concept maps for gonorrhea, syphillis, herpes, and venereal warts have led to the design of prototype SmartBooks for each of these diseases. The evaluation of these prototypes led to the following design features for the HyperCard SmartBook stacks:

(1) Every card has a name by which it can be referred to.

(2) Every card has text field covering the bottom third of the card with possible scrolling.

(3) Card name buttons are rectangular and not clickable.

(4) The path taken to reach a particular card can be derived by clicking the node to the left of the shaded card name button.

(5) The number of nodes on a card does not exceed 10 and is usually less.

(6) Auxiliary buttons at the bottom of each card include 'To Map" and "Glossary" buttons as well as a "Disease Start" button. The To Map button links to the disease concept map highlighting the source node (card) which the user has just left. The Glossary button offers two modes of operation:

   (a) the complete glossary of all defined words and

   (b) selection of the any word in the text which may (or should) be in the glossary.

(7) Leaf nodes of each card operate as scrollable pop up window when clicked.

(8) Additional special buttons on several cards near the front or back of the stacks include:
   (a) "Disease Text" which when clicked presents the complete scrollable text for a disease, and

   (b) "Reference" button which when clicked presents a complete set of references for the disease in question.

(9) Each stack has an introduction/help facility which explains the operation of the slack and any special features in addition to those defined above.

7.4.2 Use of (he STD SmartBook with learners

The STD SmartBooks (with emphasis on the AIDS SmartBook) have been presented and tested with undergraduate nursing students. We are interested in how they access the information and how they interact with the system. A general introduction to the Macintosh computer emphasizing icons, pull down menus, and point and click techniques was presented to an entire class. The students were asked to conscientiously use the STD SmartBook and familiarize themselves with its form and functionality, while at the same lime attempting to be critical of its domain knowledge, style of presentation and human interface. Eleven students were interviewed as they used the system. This led to the detection of a number bugs and improvements in the design of the system.

More recently (summer, 1991) the doctoral dissertation research of Carol Wood is specifically addressing the question: Does the use of an expert-constructed concept map representing a knowledge base about AIDS facilitate student learning of the content represented in that knowledge base, via a microcomputer-based piece of software (the AIDS SmartBook)? Our hypothesis, of course, is that learning will be facilitated when concept maps are used as described.

To answer this primary research question Wood has pursued two lines of experimentation: a qualitative component and a quantitative component. Both components involve two stimulus conditions, namely, the AIDS SmartBook as it has been designed, and a control program where linking only occurs through topic headings at the beginning of the program, or from the end of one one sub-concept to the beginning of the next The control program does not make any use of concept maps.

The qualitative component entailed semi-structured interview/observations which served as a pilot study for the purpose of gathering information about perceptions of students using both versions of the SmartBook. Twenty-eight interviews with nursing students gathered a great deal of general information about students' opinions of computers, students' perceptions about features such as pop-up windows, scrolling text, and pushbuttons on the screen. The interviewer also asked student users specific questions about their understanding of the material presented onscreen as well as their feelings about their interactions with the system. Student use has been monitored through individual interviews during interaction with the program (Wood, 1991).

Two pervading themes were revealed: (1) Although many suggestions were made by students for how the program's ease of use, readability, or comprehensiveness could be improved, the most consistent criticism was the inability of the SmartBook to let the user know which areas of the large (15 node) AIDS concept map had already been visited.

Use of the "TO MAP" feature does reveal clearly which card (subconcept) had been visited just prior to viewing the general map. This criticism could easily be remedied by uniquely shading or coloring nodes which have been visited in the general AIDS concept map. (2) In comparing the two programs, all students with the exception of 3, consistently stated that they preferred the SmartBook featuring concept maps. Reasons given for this preference most often referred to its "gamelike" quality, increased freedom of movement within the knowledge base, or greater visual appeal.

In the quantitative study, some 50 subjects have been given an AIDS SURVEY Pre-test and then randomly assigned to either the SmartBook or control program. Basic demographic questions and questions about experience with microcomputers are asked while maintaining the anonymity of all subjects. A later Post-Test enables evaluation of what learning has taken place, what parts of the SmartBook have been used. Such records of paths pursued and analyses of answers to questions about AIDS knowledge should prove very revealing. Although the data is not yet analyzed, with each subject answering some 50 questions in total, we expect some interesting results.

Preliminary results indicate that the program is effective in providing relevant information on AIDS and will help guide the further development of our intelligent tutoring system. It is our expectation that the flexibility of the SmartBook/concept map approach will enable students to learn in idiosyncratic ways and thus enhance meaningful learning about STDs. We also believe that because of the facility for rapid access to interconnections between various concepts that students will appreciate the system's ability to help them process information quickly and help facilitate the learning of clinical decision making processes.

7.5 THE STD/ITS EXPERT MODULE

In addition to refining the concept of the STD SmanBook, we have developed an expert system based on the medical information embedded in the STD semantic network. It is our expectation that the expert system will be used in the STD/ITS in order to help the learners understand the relationship of general STD concepts to specific diseases. For example, after a learner has traversed the SmartBook and assimilated some knowledge he/she will be able to ask the expert system what types of preventative measures can be taken to avoid infection. Our expert system can men lead a student through an analysis of all relevant AIDS SmartBook concepts, including, for example, signs, symptoms and treatment and prevention techniques.

The expert module in our system contains the accumulated medical knowledge related to AIDS and provides domain intelligence. It acts not only as the source for the knowledge to be presented (this includes generating explanations and responses to the student as well as asking the student questions), but also serves as a standard for evaluating student performance. The enormous amount of knowledge in complex medical domains such as AIDS and the possible interrelationships of that knowledge means that the design and development of the expert module may be the most demanding task in

building an ITS. As Anderson (1988) points out, the expert module is the backbone of any ITS. A powerful instructional system cannot exist without a powerful body of domain knowledge.

The construction of an intelligent tutoring system to represent the knowledge bases of coin experts and novices allows us to assess learners' knowledge and how that knowledge changes over lime. The expert module of an intelligent tutoring system is critical to the success of any effort to develop effective tutoring. Through a series of production rules (if then rules) expert systems can represent and embody the accumulated knowledge of human experts. Whether that knowledge is in a procedural or declarative form (Feifer, 1988) the difficult problems which must be solved
are: (1) How can expert knowledge most accurately be encapsulated ? (2) How can the expert knowledge (rules) most effectively be employed for intelligent tutoring?

Traditionally, expert systems have been employed to facilitate decision making by enabling problem solving. The critical issues of the domain in question, STDs, are not problem solving, but rather conceptual understanding (or misunderstanding) and the efforts to detect, represent and evaluate them. The expert system and a student's interactions with it will lead lo the evaluation of the student's conceptual beliefs (student modelling) and the choice of a tutoring strategy. The expert system, with its rich knowledge base, can ask the student a number of questions to test both factual (declarative) and conceptual (procedural) knowledge.

Earlier experience from an effort to construct an AIDS expert system taught us to avoid any attempt to perform diagnosis. That is nor the role or the purpose of the STD/TTS. It should try to understand the student learner's conceptualization of the domain in question and based on the analysis of it, attempt to inform, instruct, and support healthy behavior modifications.

We have emphasized that a great deal of effort needs to be expended to encode a large body of knowledge into the system. How do we explicitly go about encoding knowledge into the ITS data structure? There are basically three approaches, each moving toward a more cognitively faithful representation of the content expertise (Anderson 1988). The first is the completely opaque or "Black Box" model which does not require us to actually codify the underlying human intelligence. It produces instructions based on differences between the student's actions and expert performance. The second approach, the "Glass Box" model, basically entails the standard stages of development of an expert system. It involves extracting knowledge from a domain expert and devising a way to codify and apply that knowledge. Each reasoning step can be inspected and interpreted in this kind of model. The third approach attempts to construct appropriate "Cognitive Models" of the student learner. Such models can vary in their degree of similarity to the knowledge used by human domain experts and are most difficult to develop.

7.6 RELATIONSHIP OF THE EXPERT MODULE TO EXPERT SYSTEMS

It is worthwhile considering the relationship between the expert module and the expert system as it is known in AI. There are two notions of expert system (Anderson, 1988), one that is closely related to a certain methodology and a second one that is criterion-based (see Fig. 7.4). A "knowledge-engineering" methodology, a term introduced by Michie (1985) has arisen for developing an expert system. It involves the extraction of knowledge from human experts and its transmission to a computer's memory. when we refer to expert systems, we refer to the products of this methodology.

Another definition of expert systems would be those which are criterion-based. Slatter (1987) tries to clarify this approach, describing it as the performance of "cognitive simulation". cognitive simulation seeks to emulate human thinking and to embody it in an expert system, not just as the knowledge of the domain expert, but also as the way an expert presents, utilizes and acquires knowledge. Any system which achieves this high performance simulation could be classified as an expert system. Since the expert module in an ITS should be capable of using an explicit strategy for emulating human cognitive processes, it would be considered an expert system by the criterion-based definition.
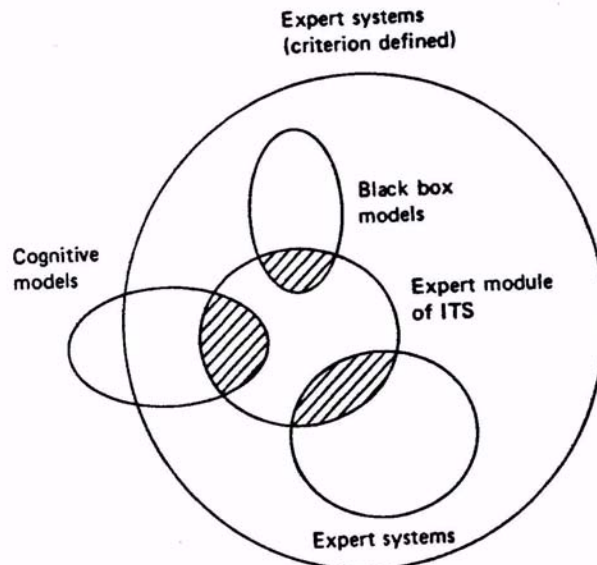
Fig 7.4 -- The set relationships among cognitive models, black box models, expert
systems, expert systems criterion-defined, and the expert module of an ITS

In particular, cognitive models would be expert systems if they model ways to solve complex problems, including the ability to understand a student's misconceptions. From this point of view, we also need to integrate some methodologies for building an expert system into a cognitive model and explore an appropriate interface to develop a direct link between knowledge engineering methods and cognitive approaches.

Fig. 7.4 illustrates the set relationships between the models we have presented thus far. As can be seen, the criterion-based expert system is sufficient, encompassing

everything except those cognitive models that concentrate on emulating neural processing, that is models of how the brain works. Black box models, knowledge engineering defined expert systems and cognitive models all intersect with the expert module of an ITS.
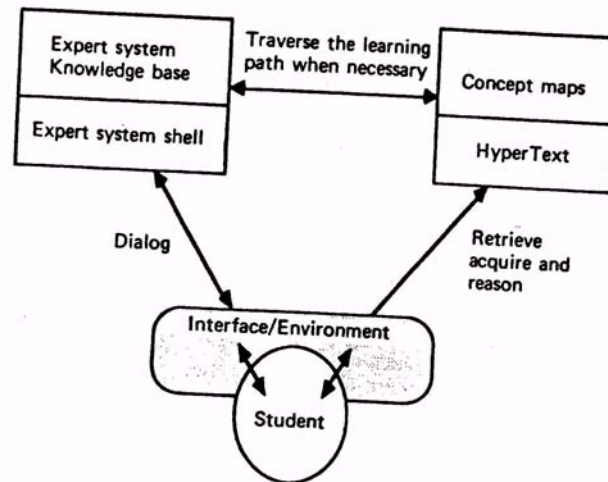
Fig 7.5 -- The expert module and its interaction with the AIDS SmartBook.

Stemming from the foundations of the ACT learning theory, the objective of our design is to: (1) Extract expert knowledge and represent it in concept maps. The student learner can traverse a concept map to retrieve knowledge and new concepts into existing familiar concepts. Some reasoning processes by the learner may also lake place. (2) Construct a rule-based expert system which contains questions for testing of understanding of the key concepts relevant to AIDS. The questions are grouped corresponding to the hierarchical level of the learning path in the branches of the concept map and are ordered according to statistical data from tests. The system interacts with students by asking a series of questions (see Appendix 7.1). (3) Link each question to a relevant branch of the concept map and guide the student automatically through the appropriate learning path to acquire the correct concept if the student's answer during the dialog is wrong. All these goals incorporate the desirable features of a cognitive model which were discussed earlier. Fig. 7.5 shows how the AIDS expert module interacts with the student.

7.7 LINKAGE BETWEEN THE EXPERT SYSTEM AND SEMANTIC NETWORK

As mentioned earlier, there are two components in our expert module. One is the cognitive model we designed above, and the other is an expert system. In this section we will discuss why we need to develop the expert system and how we connect it to the cognitive model.

As is the case in knowledge-based systems founded upon semantic networks, the purpose of an expert system is to transfer knowledge. What these two systems have in common is a knowledge base through which the student must learn. Again, here we assume that students are using expert systems or exploring concept map representations because they are interested in learning something.

The semantic network designed above is linked knowledge, a pure hypertext knowledge base (KB) which is the map and the hypertext software for accessing the map. Although the system enables the transfer of expert knowledge to the student learner, the student is in complete control. We cannot guarantee that real learning takes place with no expert-imposed constraints. At least, we are not sure that the learner will ever follow a main learning path and be exposed to all of the key concepts in the hypertext KB. He/She may either believe that these subconcepts are not relevant or interesting enough to attend to, or fail to realize that these categories of information are important. The result of the hypertext approach to knowledge transfer will be uneven.

Therefore, we also need an expert system to interact with the student to determine the level of understanding, and take action to produce a higher level of understanding or lead the student through the hypertext KB. An expert system consists of two major components, an inference engine and a knowledge base. The inference engine is the part of the software that processes knowledge to produce recommendations and answers from a set of conditions furnished by the knowledge base and the user. The knowledge base usually consists of facts and rules about how to deal with facts.

The prototype of our system consists of a series of dialogues between the expert system and the student The student answers questions posed by the system. Based on those answers, the inference engine fires another rule which results in another question being asked, or advice being given immediately, or the student being taken directly to the hypertext KB in a forward chaining style. When traversing across the hypertext KB, the student Can refresh his/her learning, reorganize knowledge, and Finally return to the expert system. For example:

Expert system: A person can gel AIDS by donating blood.

Student: This is not true.

Expert system: OK. Next,   (Deeper concept)

                   It is very unlikely that a blood transfusion would give a person AIDS these days.

Student: I don't think so.

Since this is a incorrect response, the expert system will First give advice, then guide the student back to the hypertext AIDS semantic net and traverse the path: AIDS ->

AIDS Virus -> Transmission to reach the key concept card and, at the same time, pop up the "Non-Sexual" concept window.

This method of knowledge transfer provides students with a way of learning through a complex knowledge base so that they are assured of being exposed to the key concepts while remaining free to explore materials that interest them.

To build an expert system, we must obtain or develop an inference engine and then construct a KB with which that inference engine can work. In this project, we have used an expert system shell, MacSmarts Professional,^ as a tool for building the expert system. The reason for making this selection is that in addition to the shell's consisting of an inference engine and some interface components that facilitate the construction of the KB of rules and facts, it permits the developer to create links between an expert system application and HyperCard. The relationship between these three pans and the iterative nature of the operation of the expert system and semantic network is illustrated in Fig. 7.6.

Production systems, the most popular approach for knowledge representation in expert systems, form the basis of our expert system knowledge base. The questions which the expert system asks are chosen from the AIDS Knowledge Items developed in the AIDS Research & Education Project at California State University. Long Beach (Wolitski & Rhodes, 1988). AIDS knowledge items contains 29 true-false items that address key concepts in understanding about the transmission and prevention of HIV infection and the impact of AIDS on society. These questions are tested in the form of an on-line computer survey at CSU campus. Based on the data analyzed for responses by 220 users who completed the on-line knowledge survey, experts consider this the best self-quiz set as compared to questionnaire sets reported from other researchers (Wolitski & Rhodes, 1990). It is consistent with levels of college student knowledge for AIDS, and is categorized well so as to identify the key concerns of the campus community.

The AIDS knowledge items and rules used in the AIDS expert system are presented in Appendix 7.1. These rules are grouped according to their level in our path list in the hypertext semantic net and ordered according to the statistical percentage of the correct response, while the original questions were totally randomly ordered. It is noteworthy that the knowledge base covers almost all of the important branches in the AIDS semantic network and asks questions from one level to the next level in the path list, although the two research groups worked totally independently.

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┌─────────────────────────────┐
│   Expert  System   Shell    │◄───────┐
│     (Rule  Interpreter)     │        │
└─────────────────────────────┘        │
   │                                    │
   │                                    │
   ▼                                    │
┌──────────────────────┐   ┌─────────────────────────┐
│  Knowledge   Base    │   │  Semantic    Network    │
│     (Rule Set)       │──►│     (Concept  Map)      │
└──────────────────────┘   └─────────────────────────┘
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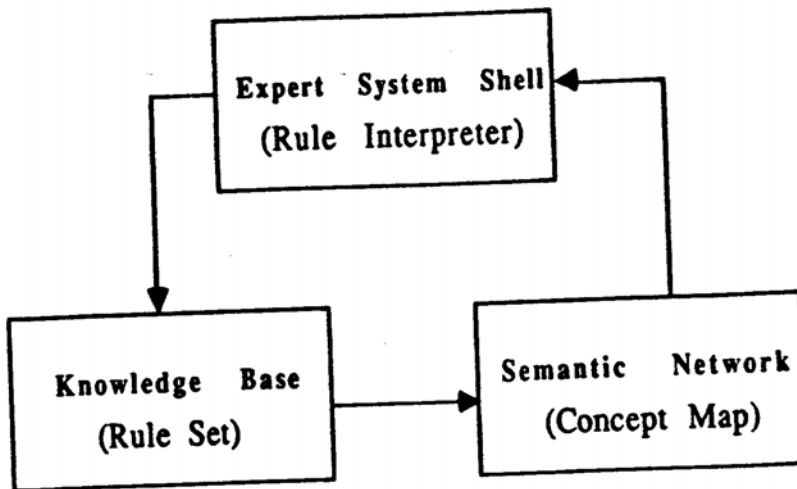
Fig 7.6 -- Rule-Based expert system interacts iteratively with the semantic network as indicated.

Some generally accepted principles in software engineering and techniques for constructing production systems that have been used in the design of the expert module are:

Separation of Concerns - Note that the three-part structure of rule-interpreter/knowledge-base/semantic network   provides a very effective separation of the knowledge base from the inference engine. The knowledge base composed of production rules is essentially "pure knowledge" since it need not contain control or programming information. This clear separation makes the knowledge easy to access, identify, and modify.

Modularity and Modifiability - Production rules encode discrete knowledge items which are generally unrelated to other production rules unless there is an explicit production rule relating them. Items can be treated as a collection of independent facts which may be added to or deleted from the KB with no "side effects". This modular feature allows the expert system, like good human experts, to continue to grow in its KB and assessing capabilities as more understanding of AIDS become available.

Simplicity and Expressiveness - Since our expert system is organized in terms of a correct answer or advice, the uniform structure of the If - Then syntax in a rule-based system provides a language in which the representation of expert knowledge is very simple and natural. The simple syntax of production rules improves the readability and tends to be self documenting.

This design answers the question raised earlier in this chapter "How to supply a link between the cognitive approach and the expert system?" The result can be very effective. It can guarantee that students, assuming that they are present and reasonably alert, will at

least be exposed to the concepts which are critical to the learning of the subject matter. Students, on the other hand, may also enjoy their learning experience.

In summary, the expert module is organized around learning, more specifically/around the successful integration of new material into the student's existing knowledge. This requires pedagogically oriented pieces of domain knowledge to be included, such as rationales for explanations in terms of goals and causes, as well as conceptual relations between pieces of knowledge that facilitate the use of abstraction.

Much of the foregoing discussion and details on expert systems and their relationship to the expert module in an ITS is based on Chao Cheng Shi's thesis (1991).

7.8 TOWARDS AN INTELLIGENT TUTORING SYSTEM

Recent advances in learning have taken a particularly cognitive perspective (Carey, 1987) and many of the major findings have implications for education in general and the development of intelligent tutoring systems in particular. This perspective begins with the principle that what learners already know about new information will influence their subsequent learning of that material (Champagne and Klopfer, 1984). This is consistent with William Martin's Law (1978) which states that: "You can't learn something unless you almost already know it." The idea behind this is that learning rules from examples is most effectively accomplished by being able to isolate the smallest, but most significant different features of counterexamples. From this point of view the ways in which undergraduate nursing students access the STD SmartBook will be compared with how the medical experts constructed the original STD semantic networks. This information is integral to the construction of a student modeler in the STD/ITS since student models must be compared to expert understanding in order for the tutor to make appropriate suggestions for subsequent learning events.

Fig. 7.7 illustrates our perceived STD/ITS architecture and the scenario for how interaction, assessment, instruction and learning will take place. The ten steps of the learning cycle as we see it are described as follows:

1. The student interacts with the SmartBook.
2. The expert module questions the student about subjects presented in the SmartBook.
3. The student answers the expert module's questions.
4. The student modeler performs model tracing to record the student's performance (responses) in interacting with the   expert system.
5. The student modeler assesses the student's stale of knowledge.

6. The student modeler analyses the differences between the student's understanding of the content area and the expert's understanding of it.

7. The tutoring module choses a tutoring strategy and feeds it to the curriculum module.

8. The curriculum module makes known what methods of instructional feedback are available to implement a particular tutoring strategy.

9. Instructional feedback is provided to the student

10. The student may be referred back to step one for another learning cycle.

The arcs marked "(a)", "(b)", and "(c)" in Fig. 7.7 are labelled in this way in order to represent the sequence in which these steps are performed.

7.9 THE STUDENT MODELER, TUTORING MODULE, AND CURRICULUM MODULE

The student modeler will analyze students' interactions with the expert system to assess what kinds" be of a simple factual nature while others may be of a deeper conceptual nature. In either case, these may be passed on to the tutoring module for evaluation and selection of an appropriate tutoring strategy. A typical and important issue which an ITS must contend with, namely, when and how to intervene in the student's interactions with the expert system, must be resolved at this point. Should intervention (instruction) occur immediately after a wrong answer to a question has occurred, or, should this be delayed until a clear conceptual misunderstanding has been analyzed? The tutoring module's decision should depend on a pre-classification of the expert system's "question base"—that is, a question is either of a clear-cut factual (or declarative nature) or it is of a conceptual (or procedural nature). In either case, the appropriate card or sequence of cards from the SmanBook should be referred (o the student for further learning. A number of tutoring strategies inclduing Socratic dialogues, teaching by example, and graphic mapping techniques are being explored. Concurrently, a rich curriculum module may offer a variety of alternative forms of instruction, including video disks, microworld simulations like "Pat and Bobby go out for a dale," discovery learning, abstraction, problem solving, and access to specialized information networks.

7.10 CONCLUSIONS

Our prototype system serves as a testbed for investigation into a number of well known problem solving paradigms and in particular the acquisition of clinical decision making skills. Its ability to transmit information about STD detection, control and abatement will provide insight into future techniques for incorporating both expert and novice knowledge into existing knowledge bases. As each module of the STD/ITS is developed—from SmariBook, to expert module, to student modeler, tutoring module, and curriculum module, we have the opportunity for the comparison and evaluation (under

controlled conditions) of different knowledge representations as learning tools. This opportunity will not be overlooked.

We feel that our choice to represent the STD knowledge base on existing Macintosh applications is an important and practical one. The rationale behind the selection of these implementation tools is the growing concern within the AI community that systems must be developed which come to grips with the problems of applicability for the end-user. Our basic understanding of the intent of ITS development is to promote learning and this requires that the system be implemented in such a way that it is actually used by naive learners to answer their questions concerning, in this case, STDs. The growing availability of Macintosh computers on campus, pull down menus and icon-based commands have all contributed to this decision.

Although our work in the knowledge rich and complex domains of STDs and ITS still has some way to go, it is clear that a sound educational theory, supported by valid cognitive psychological perspectives (Champagne and Klopfer, 1984), will enable the construction of a powerful system. Efforts to solve intermediary problems and measure the instructional effectiveness of diverse knowledge representations will drive the further course of our research. The scaffolding for the conceptual representation which we are constructing are the nodes of the concept maps. However the foundations of our approach are links connecting these nodes and their semantic implications.

We are fortunate to live in an advanced technological era whereby a multifaceted approach employing hypermedia, including hypertext, graphics, videos, CD-ROM, and large knowledge bases, may be interconnected and interwoven in diverse and intricate ways to provide education (Woolf, this volume). However, in today's explosion of information media, both those which are smart and not so smart, opaque or transparent, as well as those which are flexible, dynamic or rigid, we must never lose sight of our higher aim here, which is to provide practical education in a socially critical domain.

7.11 ACKNOWLEDGEMENTS

APPENDIX 7.1: AIDS KNOWLEDGE ITEMS AND PRODUCTION RULES

1.1 AIDS was first identified by scientists in the early 1980's.
   Answer True   Correct: 45.3%
   If FALSE then AIDS

1.2 In some parts of the world, AIDS is found mostly among heterosexual (straight) men and women.
   Answer True   Correct: 33.9%
   If FALSE then AIDS

2. In addition to damaging the immune system, the AIDS virus may also attack the brain.
   Answer True   Correct: 33.5%
   If FALSE then AIDS Virus
                                 (Learn general rule)

3. More of the AIDS virus is found in blood and semen than in other body fluids
   Answer True   Correct 86.0%
   If FALSE then AIDS Virus -> Transmission
4.1 The AIDS virus is not spread by sneezing or coughing.
   Answer True   Correct: 66.8%
   If FALSE then AIDS Virus -> Transmission

4.2 Household pets can spread the AIDS virus to people.
   Answer: False   Correct: 61.3%
   If TRUE then AIDS Virus -> Transmission

5.1 A pregnant woman who has AIDS can pass the disease to her unborn baby.
   Answer: True   Correct: 89.8%
   If FALSE then AIDS Virus -> Transmission ->(Non-Sexual)

5.2 Breast milk can pass the AIDS virus from a mother to her infant.
   Answer: True   Correct: 24.2%
   If FALSE then AIDS Virus -> Transmission -> (Non-Sexual)

6.1 A person can get AIDS by donating blood.
   Answer: False   Correct: 72.5%
   If TRUE then AIDS Virus -> Transmission -> (Non-Sexual)

6.2 It is very unlikely that a blood transfusion would give a person AIDS these days.
   Answer: True   Correct: 317%
   If FALSE then AIDS Virus -> Transmission -> (Non-Sexual)

7. AIDS is spread by mosquitoes.
   Answer: False   Correct: 54.3%
   If TRUE then AIDS Virus -> Transmission -> (Non-Sexual)

(Learn General rule)

8. There are no cases of people getting AIDS from contact with saliva.
   Answer: True   Correct: 31.6%
   If FALSE then AIDS Virus -> Transmission -> (Sexual)

9. The AIDS virus is easily killed by ordinary bleach or detergent.
    Answer: True   Correct: 10.4%
    If FALSE then Host   (Learn General rule)

10.1 A person can be infected with the AIDS virus for five or more years without getting sick.
    Answer: True   Correct: 75.5%
    If FALSE then Signs & Symptoms

10.2 Everyone who is infected with the AIDS virus has some visible symptoms.
    Answer: False   Correct: 77.5%
    If TRUE the Signs & Symptoms -> Clinical Observation

11. AIDS-related complex (ARC) is caused by the same virus that causes AIDS.
    Answer: True   Correct: 33.2%
    If FALSE then Signs & Symptoms -> Clinical Observation -> (ARC)

12.1 People can get AIDS by eating food that has been prepared by someone who has the disease.
    Answer: False   Correct: 83.8%
    If TRUE then Prevention -> Behavioral -> Non-Sexual

12.2 It is unsafe to use drinking fountains or public toilets that might have been used by somebody who has AIDS.
    Answer: False   Correct: 76.4%
    If TRUE then Prevention -> Behavioral -> Non-Sexual

12.3 It is safe to share drinking glasses and eating utensils with people who have AIDS.
    Answer: True   Correct: 76.4%
    If FALSE then Prevention -> Behavioral -> Non-Sexual
                             (Learn general rule)

13.1 It is unsafe to shake hands with somebody who has AIDS.
    Answer: False   Correct: 92.1%
    If TRUE then Prevention -> Behavioral -> Non-Sexual
                             (Learn General rule)

13.2 Children who have AIDS can easily spread the disease to other children.
    Answer: False   Correct: 66.8%
    If TRUE then Prevention -> Behavioral -> Non-Sexual
                             (Learn general rule)

13.3 Many health-care workers have become infected as a result of treating AIDS patients.
    Answer: False   Correct: 46.1%

If TRUE then Prevention -> Behavioral -> Non-Sexual

14. A person is not very likely to get AIDS by sharing IV-drug needles with someone who has the virus.
    Answer: False   Correct 96.4%
    If TRUE then Prevention -> Behavioral -> Non-Sexual ->
                             (Don't Share, Needles)

15. If you kiss someone with AIDS, you will probably get the
    Answer: False   Correct 74.8%
    If TRUE then Prevention -> Behavioral -> Sexual -> (Kissing)

16. Latex condoms (rubbers) can reduce the chance of passing the AIDS virus from   one sex partner to the other.
    Answer: True   Correct: 92.3%
    If FALSE then Prevention -> Behavioral -> Sexual ->
              No Unsafe Practices -> (Use Condom)

17. Women can pass the AIDS virus to their male sex partners.
    Answer: True   Correct: 91.0%
    If FALSE then Prevention -> Behavioral -> Sexual ->
              No Unsafe Practices -> (Limited Partners)

18. A person is less likely to get infected with the AIDS virus through oral sex   than through sexual intercourse.
    Answer: True   Correct: 27.5%
    If FALSE then Prevention -> Behavioral -> Sexual -> No Unsafe Practices

19. There is very little AIDS among Blacks and Hispanics in this country.
    Answer: False   -   Correct: 59.0%
    If TRUE then Charts

20. It is estimated that more than one million Americans are currently infected   with the AIDS virus.
    Answer: True   Correct: 45.3%
    If FALSE then AIDS Clock

TOTAL ITEMS: 29

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