Efforts Toward an Associative Learning Instructional System

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I. BASIC OBJECTIVES

This project has been undertaken in an effort to provide solutions to some critical problems that we are facing in the field of education. In order to solve these problems we have chosen to experiment with a computer driven interactive terminal linked to an associative memory with flexible search procedures. The basic problems as we see them are:

1. The Lack of Integration of Instructional Material Within and Across Functional Fields.

If we examine the management of our educational efforts we find that in spite of the fact that we offer training leading toward professional degrees our curricula are structured in such a fashion that we teach in rigidly defined compartments. Very little effort is devoted to integrating the material in a student's major area of concentration, and even less to integrating across fields. Many of us will readily admit that we are not sure how we would, in fact, integrate this material, because we can neither master all the subject matter involved nor do we fully understand the process of association. As a result of this lack of understanding we fail to do much, if anything, and leave it up to the student to worry about trying to form a cohesive whole out of a series of disjointed parts.

While the student has, under any circumstances, to take an active part in this integration, we would hold that much more must be done on the part of the faculty to help in this process. In short there must exist some formal mechanism which can evolve over time to meet the changing nature of the integrative process.

2. The Uniform Treatment of All Students Irrespective of Background and Individual Speed in Learning.

A second major motivation in undertaking this project is the desire to improve the efficiency of the learning process by allowing the student to learn at the speed which is most efficient for himself. To achieve this end we need to develop systems which will allow flexible use of the material rather than a strict guided tour ordained by the teacher. For this reason we need systems which retain the search paths of the students, keep scores, and on the basis of the progress realized identify the next level in the hierarchy of instructional material. In order to guarantee that mismatches between students and programmed material do not interfere with the learning process, the student must be allowed flexibility to switch from highly structured material to an interrogative mode.

The flexibility which we propose will also help the educators learn about learning processes. In this way one can not only obtain a record of the difficulties the students meet, but also trace ingenious student search procedures and solutions. Such information can be of enormous help to us in learning how students proceed to structure problems for solution, and in revising the educational material.

3. The New Material Explosion

Finally we feel an increasing pressure from the rapid growth of new material. In the management field, as with medicine, science and many others, our understanding of the basic processes is growing. The increased research and disciplined observation has resulted in an ever-expanding body of substantive knowledge which must be passed on to students. Ideally we would like to teach in class only that material which is on the boundary of our understanding. That is, spend the class time discussing new concepts, recent research and generally developing sound principles from ill-structured material. This, however, we cannot do, nor can we pursue research effectively, if we have to spend all our time repeating the ever-increasing collection of well-structured material. The basic fundamentals, the well-organized aspects of our understanding, are just those facets of the material that are easiest to assign to some teaching system.

We are convinced that powerful instructional systems can be built that

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will materially affect the educational process in all three of the aforementioned areas. The development of flexible computer-driven, interactive terminal systems provides a mechanism that links the user to the two key attributes of our system. These are the associative memory with flexible search procedures and the ability of the system to learn and adapt on the basis of experience.

These features, we believe, will allow the student to choose the mode of instruction that is best suited to his learning habits, assimilate and integrate the structured material in a fashion most appropriate for that material and contextually associate it with previously learned matter. As for the educators, the system will provide a management tool that is critically needed, as well as focusing our attention on the instructional process.

While the use of flexible interactive terminals is no automatic panacea, indeed they necessitate the expenditure of considerable effort in material development, it seems to us that this approach has considerable potential. Hence our basic long-run objective is to develop such a terminal system.

In the shorter-run, our objectives are quite specific. We wish to establish a flexible interactive terminal system at the graduate level to be used for experiments aimed at developing our long term goals. This system is being used initially in the management accounting field.

II. SYSTEM CHARACTERISTICS

Our objective has been stated as a flexible interactive terminal system for use in higher education. We feel that provision of a truly flexible system requires certain fundamental characteristics which have not previously been tested, to our knowledge, in connection with the learning process. (1)

A. Semantic Content Association

The first of these is the use of a semantic memory, (2) with associations based on the content of information, not its location. This characteristic provides the necessary flexibility which allows the students to address the system in natural language and to follow paths through the material that are relevant to his line of questioning.

The design and use of a semantic memory implies a certain formal structuring of the information content, at least initially. Unfortunately, there has not been enough development in our understanding of the structure of natural language to allow complete freedom to the user. However with structured material this is not a serious limitation as there is a "natural" formality to the subject matter which does not impose any severe limitations on the user. Often the recognition of key words is a sufficient base from which the system can start.

Potentially a system with semantic memory offers advantages both at the input and output stage. Its associative characteristic can allow automatic reorganization of the data base content each time a new declarative statement is entered. Greater efficiency in both storage and retrieval of information is thus assured as all relationships between concepts do not have to be inserted and stored explicitly. Furthermore, the semantic memory can use the stored information as building blocks to provide output that was not specifically entered into the system, and eventually support logical inference. This becomes necessary with any complex body of material as it is clearly inefficient to store all meaningful combinations of factual statements. (3)

This brings us to one of the greatest limitations of present "exhaustive" semantic memories. (4) We have said that semantic memories in general are efficient in terms of associating new declarative statements with stored information, and also retrieving information that is specifically structured in response to each particular question. That much is true. This capability, however, is based on an exhaustive storage of all the different meanings of each concept. If erroneous or even ambiguous definitions are originally introduced, erroneous relationships among concepts will be constructed. Furthermore, the memory of even the largest computer becomes cluttered with the storage of a score of concepts.

In contrast to designing an exhaustive semantic memory we have concentrated on selectivity. We decided to store only the most appropriate hierarchical relationships among concepts rather than list all the attri-
hutes of each concept. In this way we limited the "inventionness" of the system but achieved efficiency in storage, expanded the breadth of our system and also limited the misleading associations. The system may occasionally present innocuous relationships but these are easily recognizable because of the limitations imposed on the relationships among concepts.

Our system depends on associative memory software schemes in which linkages are by substantive content rather than physical address or location. This is necessary to allow retrieval of adequate responses to questions where there is no one-to-one correspondence between the question and the content of the answer in memory.

B. Capability for Learning

The second major distinguishing characteristic of our system is the importance we have attached to the system's ability to learn. It is central to our notions that we build a system that is able to monitor the user, recognize patterns in his behavior and adapt accordingly. This characteristic has been recognized as being desirable by others before us, but we are suggesting something beyond what we think we have seen discussed in the literature. We feel the system can be made to exhibit a certain degree of intelligence. For example, it can monitor the user and retain information on his stated objectives, the types of questions he asks, and also evaluate (or update) the user's performance level by analyzing his responses to the system's questions. In this fashion the system can associate objectives with successful search procedures and guide subsequent users toward an efficient search path.

To achieve this goal the system must have:

1. Pattern recognition capability at a level adequate enough to identify significant patterns in user activity as they develop. This implies the development of a model of the user that is powerful enough to represent his current level of understanding of the material in question.

2. Adaptive characteristics, such that the system can modify its responses on the basis of experience. Thus, not only is pattern recognition required but also identification of the key variables in the learning process and of the specific attributes of the material to be taught so that the two can be matched.

C. Hardware Characteristics

We accepted as a premise, that the physical conditions in the use of the system must not interfere with the user's natural learning process. There must be no inflexibility due to time delays, or awkwardness of specifying and receiving responses from the system. On the basis of our experimental use of the system we have found that students get very impatient with the speed of present remote "typewriter" terminals. Furthermore, the concentration on the word by word output as it is printed out draws the student's attention to the minute detail (limited content) at the expense of the pattern of relationships (meaning). The dynamic aspects of information association are not, therefore, fully brought to bear and the learning process is somewhat inhibited. For these reasons it became clear to us that some form of visual display terminal is absolutely essential.

Technology is changing fast in this field but our preference has been for a general purpose display, with light-pen or RAND Tablet and telephone connection. A Cambridge, Massachusetts firm is marketing such display for approximately $15,000. For our purposes, at a University level, this seems to result in reasonable cost/effectiveness figures.

In terms of computers, we are presently using the MIT Computation Center's time-shared IBM 7094. Large files are an inevitable part of educational systems so smaller computers have not been particularly attractive. It is also apparent to us at this point that a multiprogrammed, partitioned, system would provide a more cost/effective system for driving educational terminals than the fully time-shared versions.

These three problem areas form the core of the material to which our project is directed in both the short and long run. The following sections discuss in a little more detail our implementation strategy and progress toward these goals.

III. IMPLEMENTATION STRATEGY

The long-term goals and system characteristics that we have described
above represent a minimum set to support the kind of learning we think is desirable at a university level. Clearly our state of knowledge in the various fields involved is not adequate enough to allow us to construct a fully associative system. Our strategy, then, was to create a short-term, but functioning system that was compatible with our long-run goals even though its characteristics were extremely simple. In other words we wanted to build a first-level sub-stability that does work, experience with the system, modify our approach as experience dictates and then proceed to the next level.

First-level system

We felt that our first-level system had to be able to perform three types of functions:

(a) Respond to Questions

That is, allow the user to ask the system any relevant question in relatively free form and receive some reasonable response, even though the latter may instruct the student to consult with the Professor. The system achieves this capability by concentrating on key words and recognizing the "meaning" of terms such as "what," "when," "where," "what for," "relationship between" etc.

(b) Tutor and Test

The system provides the student with sequenced questions (programmed instruction) to which he responds with light-pen or keyboard. The answers are interpreted by the system, and an appropriate response given.

(c) Pose and Solve Problems

The system provides the user, or vice-versa, with a problem and monitors his problem-solving process. The dynamics of the system, together with the graphical abilities of the terminal provide a powerful analytical combination. Dynamic "break-even" charts, or "T" accounts are typical accounting examples of this capability.

(d) Allow a teacher who knows little about computers and software to use the system and also introduce new material. For example the teacher may decide to construct a short sequence of programmed instruction questions to supplement existing branching alternatives. He can do without having to acquire technical knowledge in the area of computers.

We would argue that these four functions are the minimum set necessary if the system is to perform adequately as a "teacher." That is, if it is to be able to reduce the "understanding gap" discussed above. The "Associative" aspects of the system are all applied in the question answering phase of the project (in (a) above). This provides the basic core, whereas the Tutorial and Problem Solving packages are called upon as needed, by the students progress through the associative memory.

In other words, at different stages in the learning process different pedagogical tools are likely to be more effective. Operationally the system would lock in on the concept inherent in the student's questions, pose numerical problems and/or suggest programmed material until the student is responding with right answers. When the system is satisfied, control would then be passed back to the student. This process would continue until the student is satisfied or finished. The path followed in this process is a function of the student's understanding and his pattern of responses.

The four problem areas discussed in Section II (associative memory, pattern recognition, adaptive characteristics and flexible hardware) have varying degrees of emphasis in this first system.

By using a simplified version of a semantic memory we have achieved a reasonable degree of flexible search. Accounting has some inherent formalism in its terminology so we can use "natural" accounting English language to ask questions of the memory. Building on this inherent structure, we have been able to construct an adequate working system that appears to the user to be answering natural English language questions. In fact the system identifies the structure and responds from there. For example, to the question: "What does an asset mean in accounting?" the system responds, "An asset is a form of capital." The question is recognized in this instance by two key words, 'what' and 'asset,' the system interprets these on the basis of its rules, and returns the answer.

When dealing with the more formal aspects of accounting this degree of sophistication, although not equal to that of a true semantic memory, does provide a flexible search capability to the student.
In other words we have provided the ability for simple association. Concepts are stored in the semantic memory with links or pointers associating them to the other concepts to which they are principally related. These associations are originally chosen on the a priori judgment of the designers of the system. As experience is gathered, however, these can be reorganized to better meet the learning requirements of the users.

In a similar fashion we have provided for simple inference. The system traces through a series of levels in the semantic hierarchy in an attempt to link up the concepts raised by the user. For example the user might ask the question: "What is the connection between Title and Capital?" and the system would respond with: "A title describes an asset, an asset is a form of capital. The three main sources of capital are: Borrowing, Direct Investment by Owners or Shareholders, and Undistributed Earnings." If the student waits and does not ask another question the system assumes that he is not satisfied. It, therefore, keeps on searching and structuring new answers on the basis of the pointers that flow out of the identified key words and also out of the relevant secondary key words included in the definition of the primary key words. The system can thus continue until it exhausts itself. To avoid circularities certain rules of set theory are used to eliminate redundancy and also cut down the length of the strings.

We must stress that the inferential powers of the system are not very sophisticated but the principles followed can be used for answering quite complex questions. As we have already mentioned because of these inferential powers we do not have to store answers to all possible questions. The system constructs its own responses.

Another area of progress in the present operating version of the system is the use of programmed instructional material. This aspect of the system is like many other operating versions. Textual material is presented and the user responds with the appropriate word or words. Depending on the system's interpretation of the response, the user proceeds to some logical next step. What we have done, however, is to allow the student to switch modes between any of the functional components.

If he reaches an impasse or becomes confused with the Programmed Instruction material he can switch back to the Question Answerer and do some probing on his own, and then move back to Programmed Instructional material when he is ready to be tested. This flexible movement at the student's or system's initiation is a powerful additional feature of the system.

Conclusions

Our fundamental concern is with innovation in the teaching process in an attempt to deal with increasing subject complexity and rising costs. To do a decent job it is obvious that one has to understand something of the way people learn. This understanding of the learning process allows one to design systems using the latest technology in a reasonably optimal fashion. The instructional system described briefly here provides a useful opportunity to conduct research on the learning process itself.

We feel that we must have a mix of pedagogical tools that are appropriate to the particular student, to the subject matter in question and to the stage in the learning process that has been reached. To do this we need systems which provide much greater richness than that offered by traditional programmed instruction. We would assert that the four components of this Associative Learning Program are the basic ones necessary for an effective teaching system.

Of these components we place greatest stress on the semantic memory with flexible search procedures. This contains appropriate relationships between basic concepts. Initially these are determined on an a priori basis by the instructor but with each user the system collects more evidence on other desirable relationships. The question asked by the user, and the immediate context, determines the appropriate response by the system. Given this information the response is constructed from the basic elements by searching appropriate paths through the semantic memory. This allows much greater freedom than merely retrieving complete, predetermined, responses. The dynamic graphical problem-solving and the tutorial components are also essential but have much more in common with the many other research efforts in this field. We would assert that this com-
bination of components, together with
the associative and adaptive character-
istics of the memory, offers consider-
able long run potential.

Our initial efforts have been de-
voted to building a working prototype
which can be used as an experimental
system to establish this point and to
move us toward our long-term goals.
Underlying our efforts are a set of
hypotheses on the impact of such sys-
tems on the educational process. We
are not involved in rigorously testing
these and establishing a firm base from
which to move to the next level.

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supporting this research.

(1) Note: These characteristics have
been identified as desirable in
connection with other problems by
Kochen (1), Levien (2) and Zinn
(5) among others.

(2) Some pioneering work on this area
has already been carried out.
See, for example, Quillian (4).

(3) Another advantage of a system that
is capable of forming relation-
ships on the basis of semantic
content and constructing answers,
is that it brings us face to face
with weak logic on our part.

(4) We will call "exhaustive" semantic
memories those which depend on ex-
haustive listings of all meanings
of each stored concept.

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