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Individualized Curriculim Design

through

Computer Aided Analysis[1]

by

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and

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Introduction

For several years I have been working on a project directed toward the creation and distribution of individualized curricula for students with diverse educational goals, backgrounds, and learning characteristics. The target for our project is a system that can generate, upon demand, sequences of information about educational materials and properly organize such information in a curriculum best suited to each individual user.

There are several justifications for this specific goal. The virtue of increased efficiency in education need not be argued here; we take it as given when two-thirds of the 2300 institutions of higher learning in the U.S. are in what the Carnegie Commission on Higher Education calls "financial difficulty". The benefits of individualization have been acknowledged and pursued by an amazingly diverse range of educators, from Robert Glaser (Bolvin and Glaser, 1968) to Ivan Illich (1971). Our primary justification comes from the observation that one of the most important and sophisticated tasks of the live educator is the determination of the appropriate goals of his students and the selection and organization of materials to achieve those goals. This is not to say that the job is often done well, but rather that one of the reasons that it is usually done poorly is that it is extremely difficult. It requires that the educator have access to an enormous amount of potential material, an accurate assessment of the needs and abilities of the students, and a means to relate the two.

The problem is not the availability *per se* of information about educational materials, for that comes in a never ending stream from publishers, colleagues, special information services, professional groups, libraries, etc. Information is available not only about conventional print materials, but about every other form of instructional technology ranging from video tapes to computers, from special approaches such as simulation games (Zuckerman and Horn, 1970) to collections of course outlines (IBM, 1969) to reviews of reviews (Zimn, 1970).

The problem is the intelligent selection of materials that are relevant to specific educational needs, goals, and abilities. The history of technology in education has been to transform scarce labor inputs into reproducible and readily disseminated capital. From the invention of printing to the utilization of computer technology, the goal has been to efficiently distribute the scarce talents of the best humans in a field. In our project we are attempting to capitalize what has been a uniquely human effort: the relating of expert knowledge about an area to an educational program.

The Educational Assembly System

We call the system an Educational Assembly System (EAS).[2] It is intended to be a system that can generate information about educational materials organized in a curriculum best suited to each individual user. The potential user is a student with an educational goal ranging from something quite specific to a totally general (or ambiguous) goal. The only constraint is that the goal should be achievable by completion of some sequence of educational materials, e.g., books, lectures, films, courses, seminars, tapes, articles, or problem-sets. Given such a goal, the EAS functions as would an enlightened educational consultant who had a vast awareness of most areas, subject material, job requirements, etc., and who had the time to serve the particular needs of this individual student. Such a consultant would be expected to suggest a program of actions tailored to the student, the completion of which would accomplish the given goal.

A highly simplified sketch of the basic components is presented in Figure 1. The data base consists of two parts: a) structured descriptions of educational goals and materials (modules), and b) a network of word relationships (semantic net). Both of these are created by various subject-matter experts. The user inputs his goal, including information about the area, level, time he wants to spend, etc. Then the system interacts with questions about possible inconsistencies, prerequisites and other relevant information. The EAS programs attempt to "understand" the student's goal and then searches for modules that satisfy the goal and the side constraints. Further interactions may occur between student and system. Finally, the student is presented with the optimal curriculum. At this point, he can recycle at any desired level of detail, or he can leave the system and pursue his curriculum. (Note that the EAS does not retrieve the actual materials; it directs the student to them. In fact, it is more accurate to say that the product which the system generates is a study guide, individualized to a particular goal and student.)

A Brief Example

In order to give an indication of what the design problems in such a system, let me present briefly an example of the kind of inputs and outputs that the EAS is designed to deal with. Figure 2 shows a typical dialogue between a student and the EAS; Figure 3 shows the top level of the curriculum assignment that is produced. In a later section I will describe some of the details of this interaction.

Within-system communication: Goal Statements

One of the main problems involved in creating the system is achieving compatibility among the pieces of information that must be compared. The system needs to compare descriptions of previously completed work with descriptions of prerequisites for the target goal that the student has, or with other sub goals the student may be assigned. In addition, there is the comparison of all these goals with goals the system has stored that it can serve (such goals are "served" from the MENU, the module entry universe, which holds all the encoded modules the system can describe to the student). All these issues of compatibility are resolved by the definition of an educational goal. All goals are described in a limited, formatted mode of expression, which includes several parameters. These parameters include the area about which the goal is concerned, the level of difficulty that the goal is set at, the mastery level, motivation level, the media, and the time spent for the goal. These parameters are set depending on the type of goal being encoded. When a student describes previously completed work, he gives the area covered, the media involved, the time spent, etc. When a student described a goal to be achieved, he gives a listing of the area wanted, the media preferred, the time he wishes to spend, etc. As a result of defining an educational goal, all prerequisites are given as goals accomplished, the target goal is the goal desired, and the other goals needed for the desired goal to be accomplished become subgoals to facilitate the accomplishment of the goal. The specification of a goal, given in this formatted form, is the language of goals; it is the *lingua franca* of the system.

The most complicated part of a goal statement is the area part. It states the subject matter of the goal. Various area names can be joined with such connectives as "or", "and", and "including". The system's objective is the satisfaction of a desired goal. This is achieved by supplying the necessary subgoals so that the top goal can be accomplished by that particular student. The system may determine that previously completed work will satisfy some of these subgoals, or it may need to assign sub-sub-goals to accomplish the subgoals.

Modules

Given a particular goal, a corresponding module's purpose is to fulfill that goal. Thus a module is described by the goals it fulfills and each module represents a possible goal that a student may have. We divide modules into two types: content modules and structure modules. Content modules are associated with specific learning activating, the completion of which satisfies the goal to which the module corresponds. In such cases particular resources are retrieved (by the student) to satisfy the goal. The "prerequisites" section of a content module asks "what is needed to handle these resources?" In Fig. 4, modules 3 and 5 are content modules.

Structure modules are often associated with more general goals that are in turn dependent upon general subdomains. In this case, goal satisfaction does not require that resources be retrieved directly; instead there is the need to specify subgoals, whose satisfaction will permit the accomplishment of the original goal. In Fig. 4, module 1 is a structure module.

To exemplify these two types of modules, consider two goals: (1) "I want to learn about 'theory of the firm' at an introductory level" and (2) "I want to learn about 'management science' at an introductory level". If we wish to encode modules to satisfy these two goals, in the first case we may encode the book by the same name. The mastery of the book will be the suitable action to fulfill the goal. Prerequisites to reading the book might be an awareness of basic economic issues plus some mathematical aptitude. This is a content module. In the second case, we might structure the field of management science as consisting of the subdomains of operations research, economics, and industrial administration. Having done this, we note that the mastery of these subareas at an introductory level is a suitable action whose accomplishment will result in the original goal being fulfilled. Hence, the goal of understanding the material in this module implies fulfilling the subgoals of "learning introductory operations research, economics, and industrial administration". There is no material, *per se*, that is to be retrieved. This is a structure module.

The distinction between structure and content modules is somewhat arbitrary, but convenient. Structure modules keep decomposing goals into subgoals until a level is reached whereby there is some suitable material, or resource, or activity that will satisfy each subgoal. Maintenance of this dichotomy between content and structure preserves the modularity of the system.

Handling Real Goals: Problems of Ambiguity, Ill-structuredness, and Context

With the system as described, the task of the routines would be to compare the desired goal with the possible goals stored in the MENU, selecting one appropriately matched, expanding any required subgoals by re-entering them as yet other goals to satisfy, while checking the student's prerequisites, previously assigned modules, etc.

However there are several difficulties involved which require elaborate mechanisms to aid in their solution or resolution. We shall remark on some of them, then describe the outline of the attack. Further explication of the mechanisms will be left for the examples that follow.

The first difficulty arises when the student is interrogated for his goal. The goal must be analyzed for consistency and suitability. To do this, we must have an idea of the relevant prerequisites that the student has. Since he doesn't know what will be expected of him, we must be able to suggest the main areas he should consider when giving prerequisites. In addition, the suitability of his goal relies on the compatibility of the generality of the area he wishes to investigate and the level of difficulty he wishes to pursue. These measures must be defined in order to make estimates of such aspects of compatibility and suitability.

In addition, a goal may be specified ambiguously or poorly, the student using the wrong or improper jargon for areas he does not understand (which presumably may often be the case since he is requesting educational information about the area). This ambiguious statement must be comparable with the more properly posed descriptions of modules in the MENU, which professionals have encoded. There is also the issue of structural alterations of the goal to permit a match. That is, the goal "A or B" must be matchable against "B or A", and presumably even matchable against "B" as well as "A" since the intended meaning of "or" would allow either one to suffice. There is also the issue of context. In some contexts, an example of systems management might better be chosen as a module concerning inventory control if the area of interest of the student is management science rather than an example of an ant colony (unless the systems management concern of the student is in such a context). Determining the context is an important aid in eliminating certain classes of ambiguities as well as making better choices for modules for the student.

Finally, there is a need for some kind of interpretation of a request for an area so that related areas may be suggested that are not precisely the one requested but may well do for the student (assuming the student may have posed an essentially ill-posed goal, or in some cases one that just doe not fit the MENU's capabilities). In either case, the ability to suggest a "best try" is important if the system is to be as flexible as would be expected of a consultant. These problems are treated extensively by the system. A sketch of some of its methods will now be described below.

The heart of the solution involves the construction of a semantic net with operators on that net. The net is an extremely large collection of terms, including all terms used in the MENU of described modules, as well as many others. Each of the terms have various pointers to other terms. For each term, and its collection of pointers, one of the pointers indicates those terms which encompass or include or imply that term, another pointer indicates all terms which are essentially equivalent to that term, and a third pointer specifies all terms that are implied by, or derived from, or are subsets of that term. If all knowledge were perfectly hierarchical, we would have a perfect tree structure of the description or taxonomy of knowledge. However areas and topics and concepts (which the terms represent) are interconnected, lack a strict ordering, and are in no way strictly hierarchical. Thus the representation of this structure of knowledge involves an interconnected net, convoluted, turning on itself, and in general quite complicated. This interconnected net is the semantic net used. It is created by collecting the mini-world of higher-order, equivalent, and implied terms around any one term any one encoder uses (a specification task required of each encoder who contributes to the MENU each time a module is encoded). The system intergrates all the terms into a cohesive, complete net that includes all the mini-worlds collected and connected together.

Relaxation: approximating a good fit between goals and resources

Within the context of the assigning of modules from the MENU, the system performs a series of relaxations on the goal, as is necessary, in order to relieve some of the problems mentioned above. These relaxations take the form of a series of semantic and syntactic relaxations.

Assume for the moment that the goal of the student was "quantitative methods" at an introductory level, a desire of mastery to equal making a B in the study effort, a motivation level of 5 (on a scale of 1 to 9), any media being acceptable, and a time of 2 weeks which he has alloted. The main problem focuses on the area which we shall assume in this example matches no entries in the MENU. (Though the system performs other relaxations on the time, etc. based on an evaluation of the goal, we shall not consider them at this point;

we shall look only at the area relaxations.). One such relaxation that would occur, after other efforts failed, would be the expansion of the goal into "quantitative methods or operations research". This additional term is provided by the semantic net which would determine, by operators on the net, that the term added was sufficiently close as to permit an expansion without serious loss of intent. Later, if further difficulties continued to arise in matching the goal, one syntactic change permitted would be changing the goal to read "quantitative methods including operations research". Later, after further difficulties, a possible alteration would include "quantitative methods including linear programming", again such information coming from the semantic net. These relaxations, depending on the collected universe of understanding the system creates from the micro-views of each encoder of the modules, are at the heart of resolving problems of ambiguity as well as poor or ill-structured goals.

Essentially, the net operationaly defines the concept of "closeness" and "relatedness" of areas or ideas. Aplying these measures reduces the ambiguity to tolerable levels so that modules from the MENU may be picked which are suitable for the goals. Since another problem was a need to cue the student about relevant prerequisites he should consider noting in giving his background, the net is appropriate in this case for aiding the system. The lower (or implied) terms of the terms involved in his goal are those subareas that are highly correlated with the subgoals needed for that area (or goal). Thus the lower terms of the lower terms of... the lower terms gives a good cueing list for the student. Moreover as the student is assigned modules that are needed to satisfy his goal, the terms of the area-part of the modules form a context that defines the kinds of areas and concepts the student will be working with. When two modules with different terms are considered by the system to be suitable, the operators on the net can calculate which terms of each module are closer to (the context of) terms already assigned. This discrimination permits choices of modules which are better fits for the student. In cases where the module has the same terms, and the system is to pick between them, the mini-world around the terms of that module can be investigated by looking at the encoded module. For example, the upper category of one module on systems operations may be biology (which the encoder notes at the time of encoding the module) while the other module of the same name has computer-science. If the student is involved in programming, the net will calculate that computer science is closer to programming that biology is and chose accordingly. In this way the semantic net permits the system to resolve the problems confronting it in choosing proper modules to assign.

Creating the Data Base

As indicated in Figure 1, the EAS requires a data base consisting of descriptions of educational resources that can be searched in a meaningful way when the system is attempting to design a curriculum for a user. In this section we will describe the procedure we have devised to collect this crucial information from subject-matter experts.

A: Area definition

The first step in creating the data base requires decisions about the general size and scope of the knowledge domains in which the system will operate. For our prototype EAS, we have decided to work in the area of management science (MS). The EAS should be able to construct a reasonable curriculum for a range of students whose educational goals vary from introductory to advanced MS with an available time span of approximately 5 to 25 months. In Figure 5 we have listed some approximations of the number of modules this will require, as well as a rough mapping into more conventional academic units. We estimate that approximately fifteen thousand modules will be sufficient to span the areas of knowledge under the general heading of MS.

B: Module collection

These modules must be created and encoded before they can be entered into the system. Our collection strategy is to get a small number of top level modules encoded by subject matter experts (e.g., GSIA faculty).

Top level modules usually describe the accomplishments of an educational goal in terms of the completion of some sub-goals. Recall that we call these structure modules. Ultimately an educational goal is described in terms of some actual activity that must take place (reading, problem solving, etc). These are the content modules. Our module collection strategy is to have top-level people devote most of their effort to structure modules - thus defining the general structure of knowledge in their areas. Content modules, and lower level structure modules will be encoded by Ph.D. students, since they are often more familiar with appropriate instructional materials for relatively well-defined and narrow goals.

Encoding modules is a difficult task, even though we are using subject matter experts. The encoding forms are shown in Fig. 6a-6c, and some examples of encoding general statements into our goal language are shown in Fig. 7.

Several GSIA faculty and Ph.D. students worked as encoders, producing a small core of modules and giving up some data for estimating the labor costs of module creation, as well as suggestions for revisions in the encoding guides.

Examples of the EAS in Operation

Let's return to Fig. 4, in which the student posed the goal "quantitative methods including linear optimization." (The special word "including" is used in the system to mean "with particular emphasis on the sub-area of"). This goal was posed at the introductory level, with a mastery desired of the equivalent of Passing, with a motivation level estimated at 3, and time desired of 1-1/4 days, using video tape.

As part of the first use of the semantic net (which, recall, stores the combined collection of cognitive maps of the various experts who have coded modules for the system), the system prompts the student for prerequisites that may be pertinent with respect to this goal. In this test, the areas prompted for included:

linear optimization
quantitative methods
dual solutions, dual problems, duality
linear programming
objective functions
constraints
initial solutions
change-of-basis
sensitivity
simplex-method

The student would then respond, indicating whether he had accomplished any of these goals.

This system has no modules which are described in the way the student has stated his goal, or which even use some of his terms. Using syntactic and semantic modifications of the goal the program considered six possible choice of modules that might satisfy this goal. These included those with the area parts given by:

linear programming including prime solutions
linear programming including problem formulation
linear programming including geometrical solutions
linear programming including simplex-method
linear programming dual solutions
linear programming

Side-stepping the five which focused on some particular aspect of linear programming rather than treating it in general, as was intended by the goal, the program chose the module "linear programming", introductory, etc. Note that it also was not confused with a module within the current universe described by "operations-research" even though this is another virtual synonym with the term "quantitative methods" which does occur in the goal statement. For this goal a module is found that is satisfactory; it is given by

Linear programming/introduction,Pass,3-5,1 day.

In turn this goal has several subgoals, which expand into sub-subgoals. These are given in Figure 4. Several points can be observed in the expansion. First, when a module was assigned, and then later found appropriate again, the system reassigned it rather than assigning yet another module. When the system could find no module that sufficed to fulfill subgoals, it created dummy modules, in effect indicating to the student the necessary accomplishments he would have to achieve. Often, what the program does not do is as important as what it does do. In addition, different heuristics govern the treatment of the original (student's) goal in comparison to the subsequent subgoals needed to be satisfied. In general, subgoal modules are evaluated differently than the top-level goal concerning the relaxation allowed on the goal parameters.

The next example (Fig. 8) we enter this same goal again, but in this case, the student indicates a prerequisite of introductory linear algebra pursued at a mastery level of an A (encoded as "4") in the course, a motivation level of 6, for 6 weeks duration:

linear algebra/intro., 4, 6, 6 weeks, mini-course.

We note that in Fig. 4 a subgoal of "linear programming including problem-formulation" included the subgoal:

linear algebra or matrices/intro., B-C, 4-9, 1 week.

The program determines that the prerequisite will suffice (in fact the prerequisite claimed is much more than enough---a fact that does not confound the evaluation), and so assigns the claimed prerequisite, producing the tree given in Figure 4 with the exception that we now have modules for linear algebra, as shown in Figure 8.

In the next examples, we have a desired goal of the form "(linear programming or operations research) including simplex method," where the associated level desired is advanced, with mastery of C (or "2"), a motivation level estimated to be 7, and time to be invested of 1/2 day. This particular goal points up the capability of the system to handle very complex area-parts in the statements as well perform quite extensive and elaborate syntactical and semantic transformations on such goals. Some of the more obvious transformations included:

((operations research including linear programming) including simplex method)

((operations research or linear programming) including simplex method)

operations research including simplex method

linear programming including simplex method

simplex method or linear programming

.
.
.

In addition to syntactic transformations, the crucial semantic alterations are formed ; some simple ones include:

linear programming including prime solutions

quantitative analysis including linear optimization

.
.
.

In this particular test, the program converged to two modules, described by the areas "linear programming including prime solutions" and "linear programming including simplex method" finally choosing as the best choice

of the two, "linear programming including simplex method". It proceeds to create the rest of the curriculum part of which is given in Figure 9.

In another test, the system considered the general goal area of "operations research", generating the first level of subgoals as given in Figure 10. Each of these in turn were expanded.

Other search procedures are in evidence in these tests, though it would take a series of tests in which the desired goals and the module universe differed by some slight variations in certain parameters to cause these differences to appear. For instance the system chooses those modules whose subgoals appear satisfiable by the system over modules whose subgoals (or a smaller percent of whose subgoals) do not seem satisfiable. In addition, each parameter of mastery, motive and media is optimized against, all other things being equal, in addition to handling the complicated cases where some of each of the parameters are satisfied to varying degrees. This search goes on in conjunction with relaxation of parameters if goal analysis prompted us to anticipate trouble on some particular parameter. Finally, the system makes discriminations along "context", such a context being built up from previously assigned modules as well as other information collected during the goal-input phase.

Uses of an EAS

I have tried to sketch a picture of some interesting and important features of the EAS. The prototype system, which generated the examples described above, is currently being reprogrammed into a more efficient form. I will conclude my description with a list of several areas in which we think an EAS-like system might be useful.

1) Intra-Course Supplement

Assuming that the faculty member has supervised the creation of modules and a net corresponding to the particular course he is teaching, he may wish to offer independent studies as part of the course (perhaps toward the second half after introducing the basic material, etc.). He may wish to allow more motivated students to investigate a large number of related, adjacent, or more specialized areas with which he does not intend to concern the whole class. Such a supplementary capability would be available via the EAS system. It would act as an independent consultant in the course (or to offer another analogy, a knowledgeable Ph.D. student as an assistant in the course, though in this case, constantly available).

2) Full Course Use

A faculty member may wish to give (or see supported) a particular area in his field of interest. However, he may not wish to offer another course in that area (especially in addition to his regular load for the semester). The EAS system can accomodate such a desire. Since the system has as one of its central features a semantic capability in order to deal with fuzzy, ill-posed, ambiguous, or poorly posed inquires, it can handle students who wish to pursue some area but who have no real expertise in that area (for otherwise they might very well proceed entirely on their own with no assistance from anyone). The faculty member, by suitably supervising the net construction, can make such an independent studies course available. Such a course is given by and supervised by him; but it is largely unattended and requires little resource investment by him once the areas have been encoded. Thus a university may move from an environment of repeated course production towards one of course management where professors manage the student's progress rather than regulate it.)

3) Prerequisite Resolution

Some universities already uses an informal subsystem to accomodate students who do not have certain prerequisites. There may be video tapes on the use of certain technical prerequisites. In addition some departments may also rely on certain mathematics courses taught in the mathematics department for those who need or desire such foundations. This later resource is at times not optimal since there may be partial coverage of the material needed, or in other cases, overkill. The EAS system can accomodate the demand for quite diverse needs for prerequisite subjects that may support, impinge or intersect the particular faculty member's current course material. A properly created net allows the student to access a multitude of prerequisites at many stages (and at various levels, etc.) in subareas, as needed. Not only are such prerequisites made known (or made clear) to him, but the faculty is relieved of the burden of managing such diversions for each course. As a consequence, fewer assumptions need be made about the student, and the student need impose fewer constraints on his range of formal study. Moreover, the effort now directed in courses to establish prerequisites, which is often given limited time or resources (e.g., chapter 0 of the book), may be rechanneled elsewhere.

4) Course Design

It is expected that as a faculty member develops a richer and more elaborate network (and as the system accesses other related networks), he then can use the system for course design. By entering the profile of the normative, hypothetical student he expects to teach, as well as the goal that represents the courses' subject area, he can use the curriculum generated by the system as the basis of his own course outline for that subject area. Since the system has access to not only that faculty member's net but other nets as well, the aggregated course production capacity of the faculty becomes a partially shared resource.

5) Subject Area Definition

In conjunction with the above use, when certain formal or official areas are entered as goals to the system, the system then presents a uniform way to define the expectations of competence in that area or domain. For example, the area of artificial intelligence may be included as one of the parts of a "systems area" qualifier, at some specified level of competence. The student enters the goal of artificial intelligence at that level (together with the other descriptors allowed), and the resulting curriculum defines the expectations of the school for a student meeting that requirement.

6) Resource Evaluation

Again in the same context of a multi-net environment, the administration (or head of a depatment, etc.) may enter certain goals, representing areas or topics he wishes to see supported. Then the resulting curriculum becomes a resource evaluator. The more the system can pull together various parts of many (perhaps diverse) nets and complete the curriculum, the more the total educational system already has the resources necessary to support such a goal. The system is able to indicate the kinds of prerequisites and subgoals it was searching for but failed to find. Where the curriculum indicates missing portions is where resources need to be directed. Thus a vertain amount of inventory control is possible.

7) Generalized Program Support

By generalizing the multi-net environment to its natural limit and hypothesizing nets that cover all the areas with which some program is concerned, we can then use the system as the mainstay of the program itself. The student's main task is to move through the net, extracting the curriculum that best suits his goals and completing that curriculum. The whole program becomes defined by the system itself. For example, perhaps a college wished to support a full political science program which it currently did not have for thos students wishing to include the classical areas of political science in addition to subareas already support. However, they may not wish to invest any labor in the project (i.e., permanent faculty position). Then they might generate a net and collect the resources that were described in the net (e.g., books, films, courses at other colleges, journal articles). The EAS would act as the supplement program, making available suitable curricula, as appropriate, for a wide range of inquiry. With a minimal updating, a classical political science program could be made available, at a supplemental level. This use could of course be applied to the school or university level too.

Though these uses represent some of natural applications of an EAS at institutions of higher learning, there are other types of uses as well as other environments. One such use is university accounting. An administrator might put in hypothetical goals of interest. Assuming every module was assigned a cost, the resulting curriculum could be a measure of the cost to fulfill that goal, as all the individual module costs were totalled.

FOOTNOTES

1. This work has been supported by grants from the Ford Foundation and the International Business Machines Corporation. Steven Evans has been my collaborator throughout almost all of the design and implementation phases.

2. A preliminary outline of the EAS is presented in Klahr, Kriebal and Van Horn (1972). The design upon which the current system is based is presented in Evans and Klahr (1971), and a statement of theoretical implications is contained in Evans (1974).

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FIGURE CAPTIONS

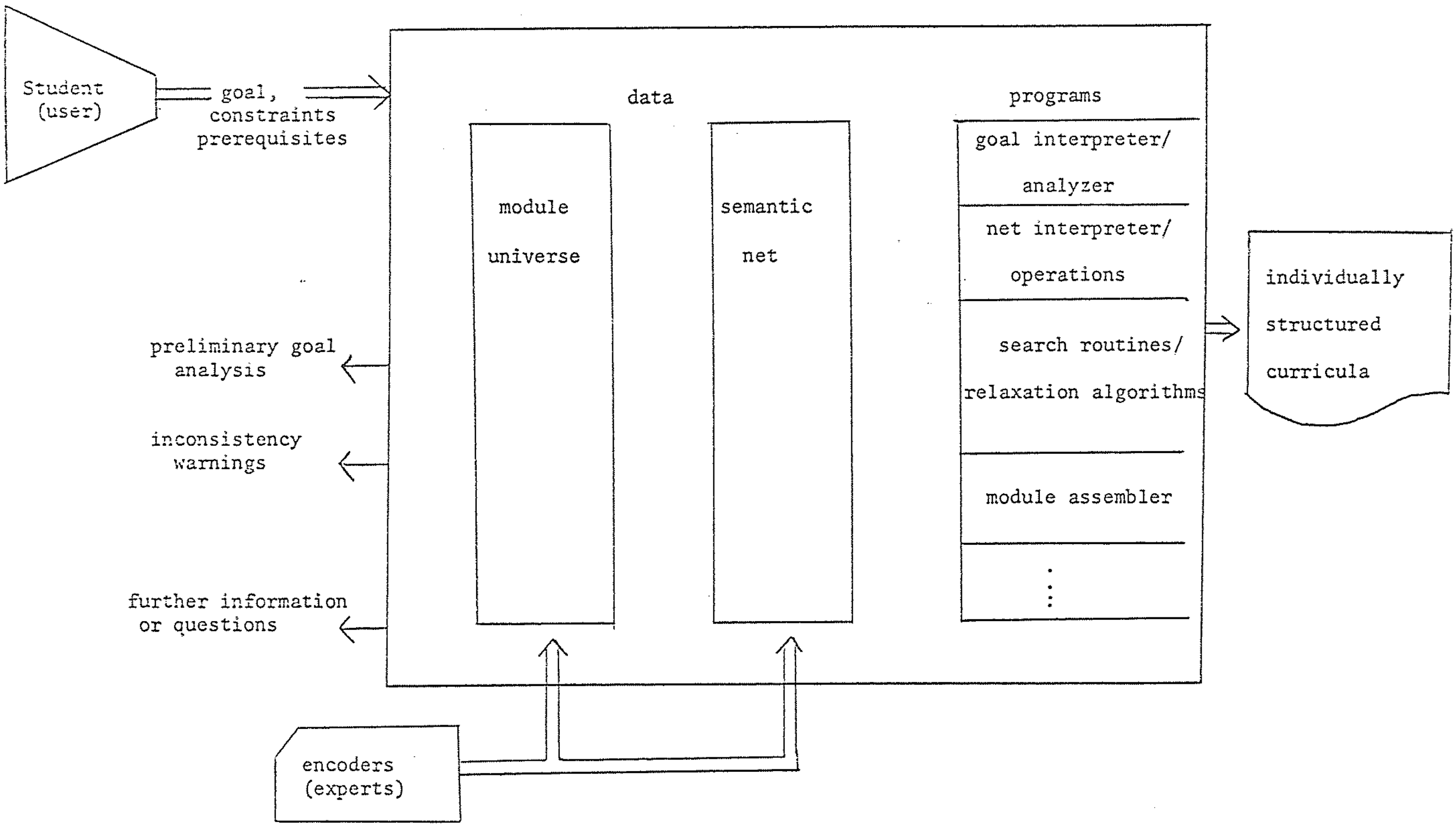


Fig. 1. Simplified schematic of EAS components

WHAT AREA WOULD YOU LIKE TO INVESTIGATE?

((quantitative-methods including operations-research) and primal-simplex-method)

AT WHAT LEVEL WOULD YOU LIKE TO PURSUE THIS TOPIC?
ENTER 1 FOR INTRODUCTORY, 2 FOR INTERMEDIATE, 3 FOR ADVANCED.

3

WHAT MASTERY WOULD YOU LIKE TO ACHIEVE?
(CHOOSE FROM P (MINIMUM-PASS), C, B OR A)
(YOU MAY SPECIFY A RANGE SUCH AS C-B).

c

CHOOSE A NUMBER (OR RANGE) FROM 1 TO 9 THAT INDICATES THE LEVEL OF MOTIVATION YOU BRING TO THIS GOAL.
(FOR EXAMPLE, 7-9 WOULD INDICATE A REASONABLY MOTIVATED STUDENT; 9 IS THE HIGHEST MOTIVATION).

2

GIVE AN ESTIMATE OF THE TIME YOU WISH TO SPEND ON THIS GOAL;
THIS MAY BE A RANGE, LIKE 2-3 DAYS, 4-5 weeks, 1-2 MONTHS, ETC.

60 hours

LIST GOALS PREVIOUSLY ACCOMPLISHED IN THE FOLLOWING FORM (AS AN EXAMPLE):
OPERATIONS-RESEARCH/INTRODUCTORY, B, 5-6, 2 MONTHS, TEXTBOOK.
YOU NEED NOT LIMIT YOURSELF TO THE FOLLOWING SUGGESTIONS, THOUGH DO RESPOND IF ONE OF THEM DOES APPLY. AREAS OF PARTICULAR NOTE INCLUDE:

(QUANTITATIVE-METHODS INCLUDING OPERATIONS-RESEARCH) AND PRIMAL-SIMPLEX-METHOD/INTERMEDIATE
(QUANTITATIVE-METHODS INCLUDING OPERATIONS-RESEARCH) AND PRIMAL-SIMPLEX-METHOD/INTRODUCTORY
PRIMAL-SIMPLEX-METHOD
OPERATIONS-RESEARCH
QUANTITATIVE-METHODS
TRANSPORTATION-PROBLEM
CRITICAL-PATH-METHOD
DECISION-THEORY

Figure 2.a

FORECASTING-MODELS
SCHEDULING-PROBLEMS
INVENTORY-PROBLEMS
APPLICATIONS
LINEAR-PROGRAMMING
PRIME-SOLUTIONS
PROBLEM-FORMULATION
GEOMETRICAL-SOLUTIONS
SIMPLEX-METHOD
DUALITY
OBJECTIVE-FUNCTION
CONSTRAINTS
INITIAL-SOLUTION
CHANGE-OF-BASIS

ENTER A PERIOD AFTER LAST GOAL
(Linear-Programming or Simplex-Method) / 2; 6W; 4; 7;

DO YOU FEEL YOU HAVE EXPRESSED AS HIGH A MOTIVATION AS YOU
ACTUALLY FEEL?
(PERHAPS YOU INTENDED A LOWER LEVEL THAN ADVANCED)
DO YOU WISH TO CHANGE YOUR GOAL? ANSWER Y OR N.

y

IF YOU DO NOT WISH TO CHANGE ANY PARTICULAR PART OF YOUR GOAL,
ANSWER WITH A CARRIAGE RETURN.

WHAT AREA WOULD YOU LIKE TO INVESTIGATE?

CHOOSE A NUMBER (OR RANGE) FROM 1 TO 9 THAT INDICATES THE LEVEL OF
MOTIVATION YOU BRING TO THIS GOAL.
(FOR EXAMPLE, 7-9 WOULD INDICATE A REASONABLY MOTIVATED STUDENT:
9 IS THE HIGHEST MOTIVATION).

3

DO YOU FEEL YOU HAVE EXPRESSED AS HIGH A MOTIVATION AS YOU
ACTUALLY FEEL?
(PERHAPS YOU INTENDED A LOWER LEVEL THAN ADVANCED).
DO YOU WISH TO CHANGE YOUR GOAL? ANSWER Y OR N.

y

Figure 2.b

IF YOU DO NOT WISH TO CHANGE ANY PARTICULAR PART OF YOUR GOAL,
ANSWER WITH A CARRIAGE RETURN.

WHAT MASTERY WOULD YOU LIKE TO ACHIEVE?
(CHOOSE FROM P (MINIMUM-PASS), C, B OR A)
(YOU MAY SPECIFY A RANGE SUCH AS C-B).

b

GIVE AN ESTIMATE OF THE TIME YOU WISH TO SPEND ON THIS GOAL:
THIS MAY BE A RANGE, LIKE 2-3 DAYS, 4-5 WEEKS, 1-2 MONTHS, ETC.

2 weeks

DO YOU FEEL YOU HAVE EXPRESSED AS MUCH TIME AS YOU NEED TO ALLOT?
(PERHAPS YOU INTENDED A LOWER LEVEL THAN ADVANCED).
DO YOU WISH TO CHANGE YOUR GOAL? ANSWER Y OR N.

n

YOUR NAME

novit, morris

PREVIOUS EDUCATION

b.a., southern methodist university.

PREVIOUS EXPERTISE

"mathematical aptitude".

PREVIOUS EXPERIENCE

none

SUBTESTS SCORES

sat, 696; gre. 705

Figure 2.c

target goal: (Quantitative-methods including operations-research and primal-simplex method)
Level = 3. time = 2 weeks. mastery = b (or 3). motive = 3. media = default

accepted goal module # 1: Operations-research and primal-simplex method,
Level = 2. time = 3 weeks. mastery = 3, motive = 4-6, media = book

target subgoal: Simplex-method including problem-formulation.
Level = 1. time = 4 hours. master = 4. motive = 5.

none assigned: No suitable module is available--temporarily assigning dummy module # G3431 Student must fulfill this goal on his own

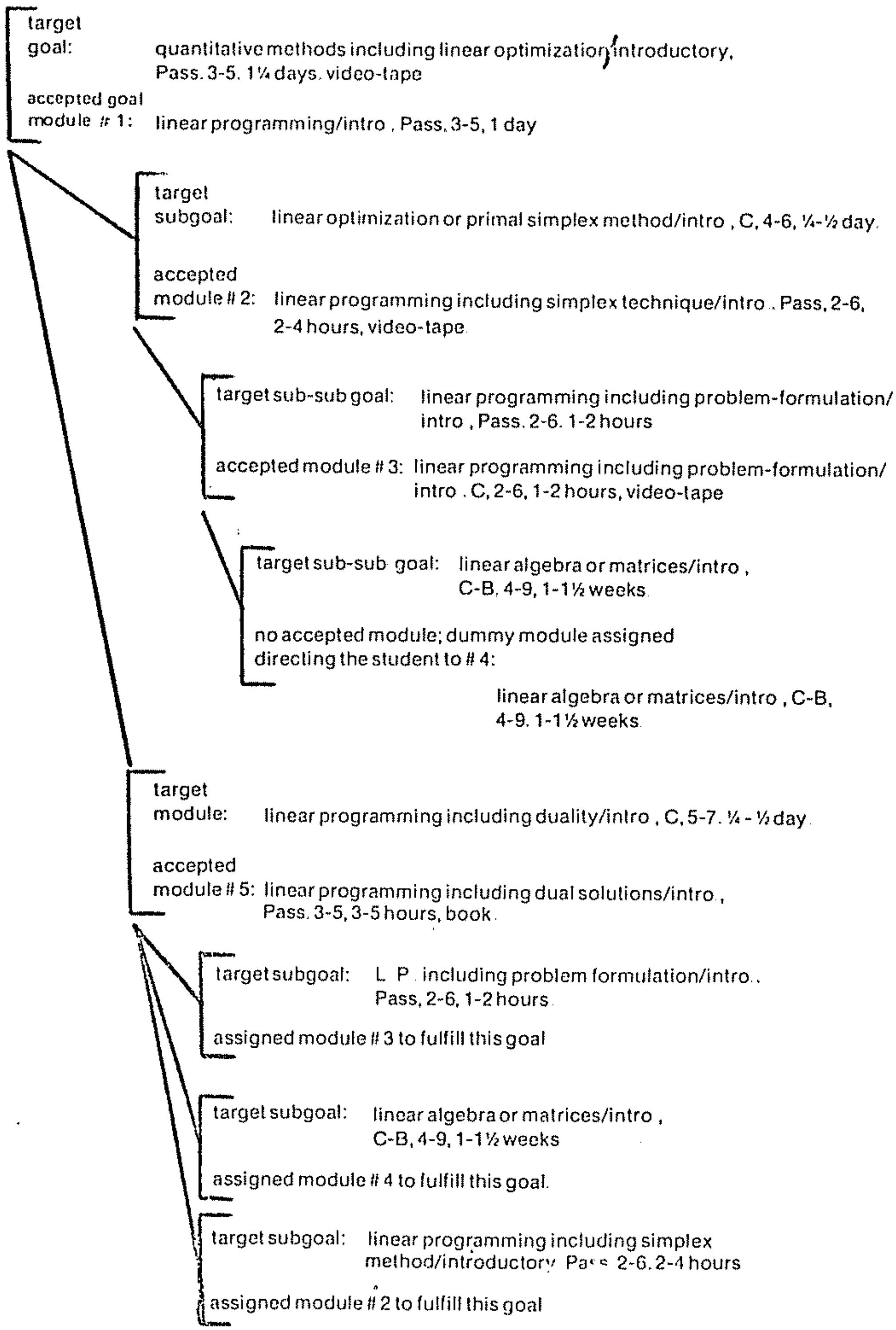
target subgoal: Linear programming including simplex-method.
Level = 2. time = 1 day. mastery = 2. motive = 6

assigned claimed module # 2: We rely on your claimed goal of linear-programming or simplex-method.
Level = 2. time = 6 weeks mastery = 4. motive = 7

target subgoal: Operations research and (simplex-method and applications),
Level = 2, time = 11 days. master = 2. motive = 7

assigned module # 3: Simplex-method applications.
Level = 2. time = 2 weeks mastery = 3. motive = 6
media = mini-course

Figure 3



EAS assignment for the goal linear programming/intro., 1, 3--5, 1¼ days.

Figure 4

I. Modules Needed

A. types of modules

Area	Level	Time (academic yr.)	Equivalence in mini-courses
management science	introductory	5 months (½ yr.)	9 courses
		10 months (1 yr.)	18 "
	intermediate	15 months (1½ yr.)	27 "
		20 months (2 yr.)	36 "
	advanced	25 months (2½ yr.)	45 "

B. number of modules

approximately 7 topics per course
3 sub-topics per topic
3 sub-sub-topics per sub-topic
63 modules per course

x5 variations of each module

total of 315 modules per course

Assuming 45 courses, we get 14,175 modules.

(In addition, assuming two calculus and one linear algebra course as additional supplement, we add 945 modules.)

Total modules anticipated: 15,120 modules

Figure 5

Size of Data Base for Management Science

Module Number ______
(plus your
name ______

Content Modules

Figure 6.a

This module is the same as
module ______
in sections ______

1. Module NAME

a. Identifying Name ______

b. Abstract: ______

c. In natural language: ______
(a sentence)

d. Given in terms of the AREA-part of the GOAL language:

e. Semantics:

w_1 = ______: A_1 = ______ A_2 = ______ A_3 = ______

w_2 = ______: A_1 = ______ A_2 = ______ A_3 = ______

w_3 = ______: A_1 = ______ A_2 = ______ A_3 = ______

Check here if other words are on back [ ]

2. LEVEL: [ ] (a number or range where introductory = 1, intermediate = 2, advanced = 3)

3. TIME (for completion):

minimum [ ] maximum [ ]

4. MEDIA (in which module is encoded):

books	course	film	audio	video-tape	computer	journal	seminar	consultation

other: [ ]

5. MOTIVE:

material suitable for students with motives ranging from to (range [1,9]

6. ACCESS:

Hunt library	Science Library	bookstore	audio/visual room

other: [ ]

7. CITATION:

a. Formal description of material: ____________________________

b. Evaluation (Score from 1-10, where 1 = quite poor, ..., 10 = excellent):

[ ]

Figure 6.c

8. PREREQUISITES:

a. Educational level needed for module

high school	college				graduate				
0	1	2	3	4	5	6	7	8	9

b. PREREQUISITE LIST:

Area/Level	Mastery (range 1-4)	Motive (range 1-9)	Time range
1. ______	______	______	______
2. ______	______	______	______
3. ______	______	______	______
4. ______	______	______	______
5. ______	______	______	______
6. ______	______	______	______
7. ______	______	______	______

check here if other prerequisites are on the back ☐

c. Aptitudes:

GRE	SAT	IQ	ATGSB	OTHER:

d. Attitudes: ______________________________

____

____

e. Other (any material of important nature allowed, to be answered "yes" or "no" by the student):

____

____

9. MASTERY

a. Mastery Level [ ] (a number or range between 1 and 4)

b. Mastery Tests

____

____

____

____

____

____

____

____

____

____

____

____

____

____

Some Examples of Encoding

Topic	Area-part of GOAL
"the art of programming"	programming
"learning to program"	programming
"how to evaluate a canned program with respect to suitability of needs"	canned-routines INCLUDING evaluation
"functions of several variables"	complex - variables
"management science applications of linear programming"	linear-programming INCLUDING management-science-applications or management-science-applications INCLUDING linear-programming (depending on intended emphasis)
"mathematical approaches to decision-making in management	management-science INCLUDING (mathematics AND decision-making)
"use of Lagrangian multipliers"	(optimization-techniques INCLUDING Lagrangian-multipliers) INCLUDING examples
"programming robots"	complex-information-processing INCLUDING robots or artificial-intelligence INCLUDING robots (depending on intent of encoder)
"describing decision making"	probability - theory INCLUDING decision-trees or decision-analysis INCLUDING decision-flow-diagram (depending on intent)
"determining and analyzing efficient inventory control strategies"	inventory-control or inventory-control-techniques (depending on intent)

Figure 7

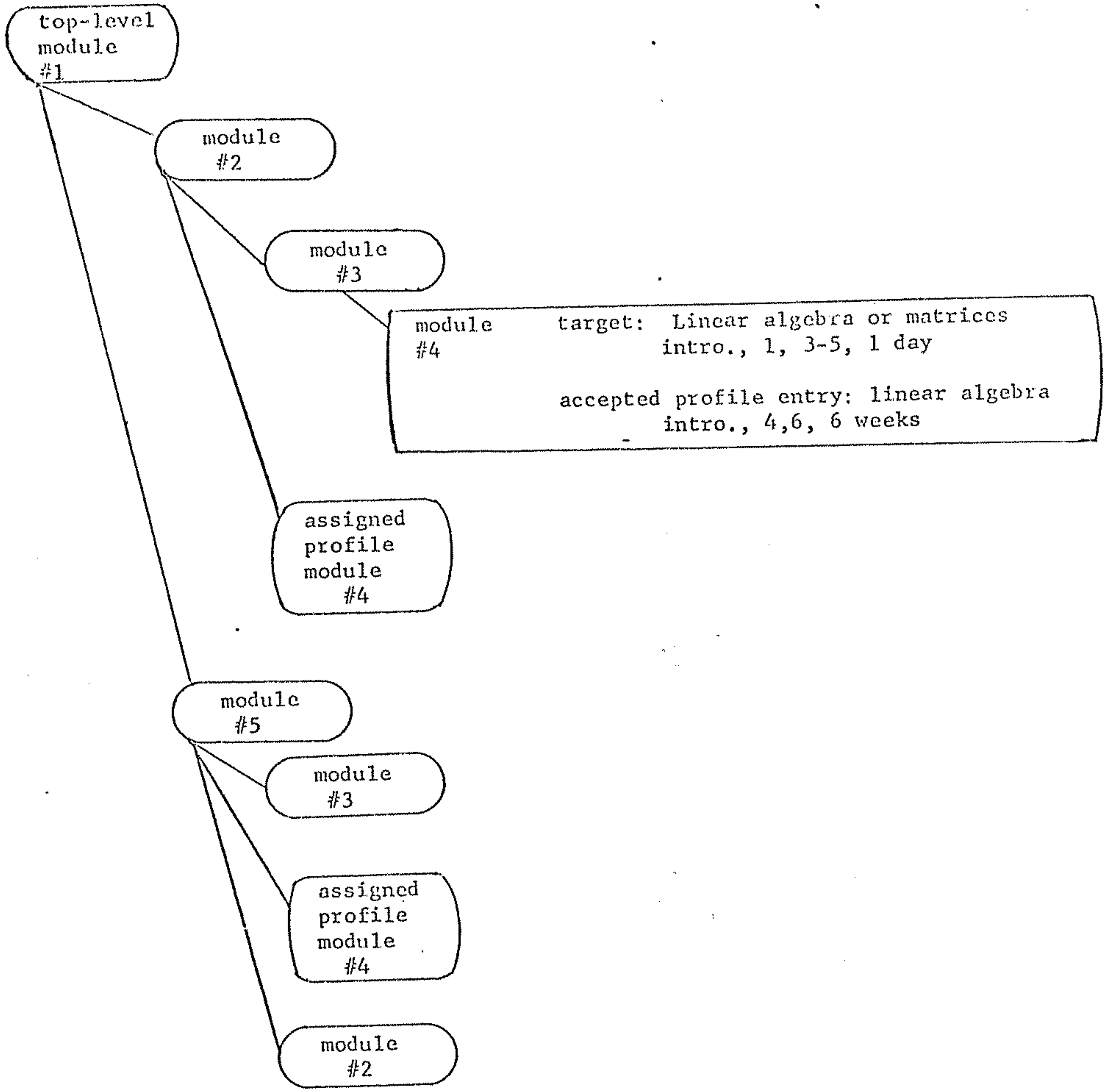


figure 8

Expansion of Goal Using Accepted Profile Entry

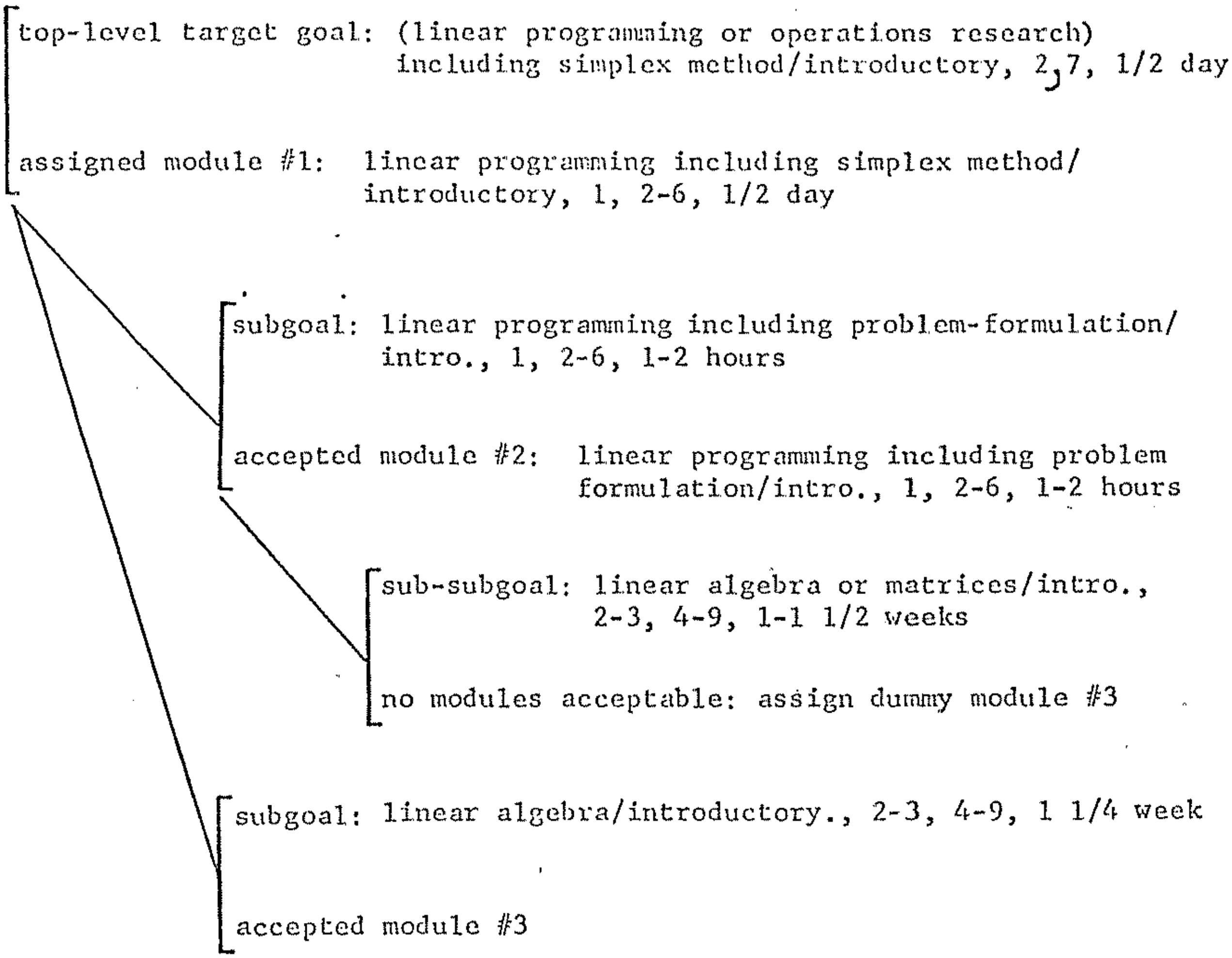


figure 9

Partial satisfaction of top-level goal

- Operations-research/1, 1, 3-5, 1 1/2 weeks
  - linear-programming/1, 1, 3-5, 1 day
    - linear-programming INCLUDING prime-solutions/1,3-5,1/3-2/3 day
    - linear-programming INCLUDING dual-solutions/1,1,3-5,1/3-2/3 day
  - transportation-problem/1, 1, 3-5, 1/2 day
    - transportation-problem INCLUDING prime-solutions/1,1,3-5, 1/4 day
    - transportation-problem INCLUDING dual-solutions/1,1,3-5, 1/4 day
  - critical-path-method/1,1,3-5,1 day
    - critical-path-method INCLUDING, problem-formulation/1,1,3-5, 1/3- 2/3 day
    - critical-path-method INCLUDING, solution-formulation/1,1,3-5, 1/3- 2/3 day
  - decision-theory/1,1/3-5,1 day
    - decision-theory INCLUDING problem-formulation/1,1,3-5,1/3-2/3 day
    - decision-theory INCLUDING solution-interpretation/1,1,3-5,1/3-2/3 day
  - forecasting-models/1,1,3-5, 1 day
    - forecasting-models INCLUDING problem-formulation/1,1,3-5,1/3-2/3 day
    - forecasting-models INCLUDING solution-techniques/1,1,3-5,1/3-2/3 day
  - scheduling-problems/1,1,3-5, 1/2 day
    - scheduling-problems INCLUDING problem-formulation/1,1/3-5, 1/4 day
    - scheduling-problems INCLUDING solution-ideas/1,1,3-5, 1/4 day
  - inventory-problems/1,1,3-5,1 day
    - inventory-problems INCLUDING problem-formulation/1,1,3-5,1/3-2/3 day
    - inventory-problems INCLUDING solution-interpretations/1,3-5,1/3-2/3 day
  - operations-research INCLUDING applications/1,1,3-5,2 days
    - O. R. INCLUDING (applications AND inventory-problems)/1,1 3-6,all,4-6 hours
    - O. R. INCLUDING (applications AND decision-theory)/1,1, 3-6, all, 4-6 hours
    - O. R. INCLUDING (applications AND critical-math-method)/1,1, 2-6, all, 1-2 hours
    - O. R. INCLUDING (applications AND linear-programming)/1,1,, 3-6, all,

Figure 10

Partial expansion of subgoals of the top-level : Operations Research