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This paper presents a summary of some recent engineering research in education and identifies some research areas with high payoff potential. The underlying assumption is that a school is a system with a set of subsystems which is potentially susceptible to analysis, design, and eventually some sort of optimization. This assumption leads to the increased application of engineering techniques which relate inputs and outputs, computer programming, simulation vehicles, control and decision theory, and many other tools to the solution of administrative and teaching problems in education. Some areas dealt with are school management, resource allocation problems, decision rules, curriculum content transmission, and curriculum content allocation. (TT)

PRE-SESSION PAPERS

on Research Methodology

presented at the First Pre-Session

of the

WISCONSIN EDUCATIONAL RESEARCH ASSOCIATION

December 1, 1967

Manitowoc, Wisconsin

The Potency of Educational Treatments

by Daniel P. Norton

Recent and Potential Application of Engineering Tools to Educational Research

by Martin I. Taft

FOREWORD

It was with considerable hesitation that the idea of holding a Pre-Session was explored. Tentative plans for holding the meeting were made but almost cancelled because of a slow initial response. However, the final result was more favorable than the planners dared hope. Over seventy persons participated in the first Pre-Session of the W.E.R.A., held during the afternoon and evening of December 1, 1967, and a partial sampling (non-random, unfortunately) indicated a considerable degree of enthusiasm for the meeting, which was designed to explore selected aspects of research methodology.

The major contributors to the success of the meeting were Dr. Daniel P. Norton of the Midwest Office (Evanston) of the Educational Testing Service and Dr. Martin I. Taft, Visiting Associate Professor of Engineering and Education at University of Wisconsin-Milwaukee and on leave from California State College, Los Angeles. Dr. Norton and Dr. Taft presented and discussed the provocative features of the two papers which are contained in this document and which represented the main themes of the Pre-Session. Dr. Norton's paper is essentially the same as presented on December 1. Dr. Taft's paper does not exactly follow his presentation at the meeting but retains the same basic ideas.

In addition, several other persons ably contributed to the meeting by serving as speakers, reactors, discussion leaders, or consultants, or by helping out with arrangements. They were:

Mr. Joseph Murnin, Chicago Office, U. S. Office of Education
Dr. Robert Hoye, University of Wisconsin-Milwaukee
Dr. Orville Nelson, Stout State University, Menomonie, Wisconsin
Dr. Robert Ingle, University of Wisconsin-Milwaukee
Dr. Norris Sanders, Cooperative Curriculum Development Center, Manitowoc, Wisconsin
Dr. Robert Remstad, University of Wisconsin-Milwaukee
Dr. Thomas Romberg, University of Wisconsin-Madison, Wisconsin
Dr. Gerald Gleason, University of Wisconsin-Milwaukee
Mr. Marlin Tanck, Cooperative Curriculum Development Center Manitowoc, Wisconsin

CONTENTS

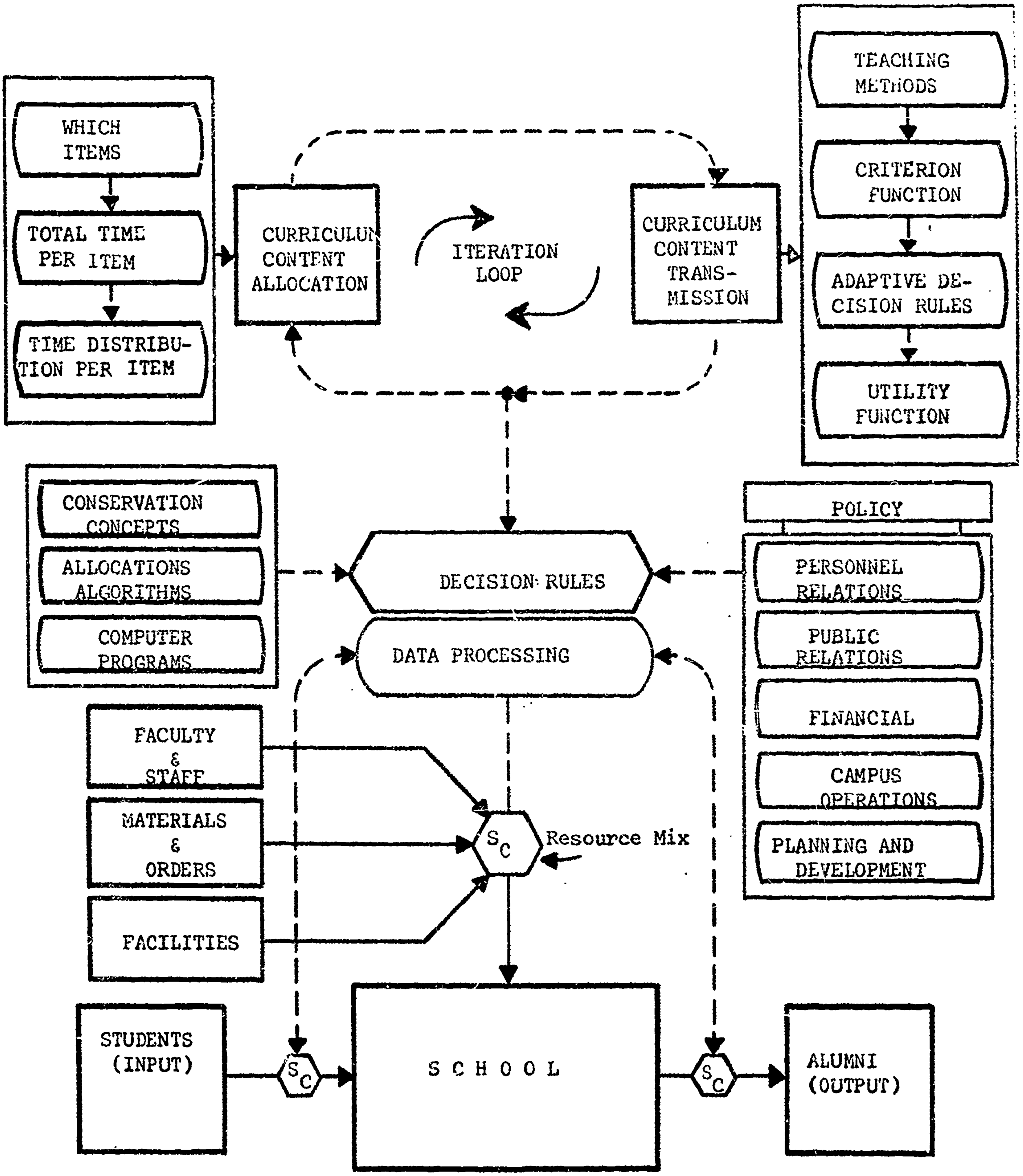


Figure 1. A SCHEMATIC REPRESENTATION FOR SYSTEMS ANALYSIS RESEARCH

The operations of an educational institution are determined by the educational objectives. From a managerial standpoint, the major objective of a school is to allocate available resources in such a way that the difference in educational potential between entering and leaving students is maximized. Students enter a school system with a given level of educational potential and hopefully leave with a much higher level. The central task of administrators is to allocate faculty, staff, material, facilities, and information at such times and places and in such proportions that the objectives of the school will be achieved in a most efficient manner.

During the past few years System Development Corporation has been developing a set of simulation models for five different types of high schools. The objective has been to develop a general simulation vehicle that permits a designer to construct on a computer a detailed dynamic model of real or proposed high school organizations. The vehicle is a simulation and list-processing system consisting of a comprehensive set of procedures written in the JOVIAL language. It is constructed in modular form so that the models can be built up by assembling the modular parts (activities, procedures, packages, modules, and total systems) into a particular configuration. An extensive series of flow charts delineate all school functions operationally. Individual or batch flows can be accommodated by what amounts to an elaborate bookkeeping system maintained with the aid of a large digital computer (1).

This is a data-handling approach which is relatively unconcerned with a specific learning theory or method of evaluating educational system outputs. It assumes that learning-teaching processes can be greatly accelerated largely on an experiential basis. Extensive sampling and use of pseudorandom population flows give data from which cause-effect relationships are relatively hard to define (2). Research in this area is still in its infancy; the need for creative research contributions here is apparent.

Michael Lackner, who has made a number of significant contributions to the development of simulation languages, has stated that "realization of the great potential of digital simulation seems to await the development of a language capable of facile expression of a wide variety of systems (3)." The application of systems analysis to educational institutions and ultimately to the simulation of those institutions on computers has caused a proliferation of simulation languages in recent years. A concise summary of basic definitions used in digital simulation and of the basic references in the field is contained in an 8-page report entitled SHARE Digital Simulation Glossary (4). A brief description of three simulation languages (GPSS, SIMSCRIPT, and SIMPAC) together with a discussion of their relative advantages and disadvantages is given in reference (5).

The technology for processing the vast amount of data generated in a school system is well developed. There is a very large body of literature which is expanding at an ever-increasing rate. Space does not permit a detailed discussion of the implications of digital computer relationships with man and social systems, but the reader is referred to the Educational Data Processing Newsletter and to an extensive annotated bibliography entitled The Administrator and the Computer, which is contained in reference (6). The bibliography deals with such diverse data processing subjects as optimal scheduling of students, college registration, self-instructional devices in counseling, construction of school simulation vehicles, administration of an automated school, computer simulation of human thinking, and sources of information on educational media.

The development of high speed, large memory, data processing equipment is already enabling school administrators to cope with the tremendous amount of information or data that must be considered in the management of a school. The ability to use all of these data is a strong function of the decision rules that are employed.

Inputs for decision rules

As can be seen from Figure 1, the decision rules in an education institution are derived from three major sources: the rules that are expressed explicitly by mathematical formulations, the administrative policies and procedures that are usually known to the faculty and staff in an implicit or verbal manner, and the curriculum. The explicit decision rules governing educational institutions are not as yet fully developed. The interrelationships between the various subsystems of a large social system like a school can be described mathematically by the application of the conservation concepts; namely, the laws of conservation of mass, momentum, and energy.

Taft and Reisman (7) have shown that when these conservation laws are formulated in general mathematical equations, the basic equations for many fields can be derived from them as special cases. An examination of the basic equations (the Navier-Stokes equations) has shown that they are limited to such areas of physical science as aerodynamics, solid mechanics, thermodynamics, strength of materials, fluid mechanics, statics, dynamics, heat transfer and electric circuits. Using an expanded form of Kirkhoff's laws for electric circuits, Reisman (8) has developed a mathematical framework which consists of K node or junction equations, M potential or branch equations, N constraint or auxiliary equations, and a methodology for their application. These equations provide for nonlinear and transient behavior of any socio-economic system as well as physical system and give recognition to the value of system simulation techniques.

Although these equations offer useful descriptions of the flow of such diverse quantities as materials, money, energy, people, and information, they incur numerous practical problems in connection with the storage, retrieval, listing and processing of myriad data or information generated in a school. Additional research is needed to determine the units of measurement for information; to dicern, measure and control impedances and potential differences in a school system; to develop techniques for handling mixed and coupled flows at a node; to generalize the equations to include mutual inductance; and to develop rational procedures for converting information which is now available regarding schools into a form that can be used in the model.

The development of allocation algorithms, particularly those concerned with the allocation of funds and facilities, has been a highly decentralized process in the United States. Although a substantial number of allocation methodologies have been in use by government and industry in recent years, few of these have been adopted by colleges and universities. Some techniques that have great potential for the growing and expanding educational institutions are:

1. CRAFT, Computerized Relative Allocation of Facilities Technique, could enable college administrators of quickly and economically evaluate many possible school facilities layouts. This technique could help to determine the optimum location on a campus of a library, the cafeteria, the computer center, and the administrative offices (9).

2. PERT (10) and other critical-path techniques could be used in the planning and controlling of the work force and financial requirements of large school construction projects.

3. CERBS, a general financial model, reduces to their present worth all disbursements and receipts involved in the possession and operation of capabilities to perform services and/or produce goods (11). This model could be used in colleges to systematically compare and evaluate a variety of policy decisions concerned with the purchase and replacement of laboratory equipment, maintenance tools, office and computer equipment, and large capital outlays.

4. Operations Research, which has been utilized with increasing success in problems related to community health services, could be applied in higher education for facilities utilization studies; economics of automating library, registration, and student health services; statistical patterns of demand for college courses; and for the development of models to describe real-system behavior (12).

In contrast with the lack of integrated basic research in the areas of decision-making described above, a large amount of work has been carried on in the areas of educational data processing of student records and the scheduling of students into classes. Through cooperative efforts between industrial organizations like International Business Machines and educational institutions like Stanford University and Massachusetts Institute of Technology, a number of comprehensive computer programs have been developed and made operational. These computer programs are being used to supply data of all kinds at any time; to rapidly and efficiently carry on the multitude of activities related to school registration procedures, record keeping, grade reporting, and budget forecasting; and to produce master schedules for assigning courses, faculty, facilities and students. A brief list of typical programs that are currently in operation together with their appropriate references follows.

1. GASP, Generalized Academic Simulation Programs, M.I.T. (13)
2. SSSS, Stanford School Scheduling System, Stanford University (14)
3. CLASS, Class Loading and Student Scheduling, IBM (15)
4. FDS, Flexible Daily Scheduling, Brookhurst Junior High School
5. SDPS, Student Data Processing System at the University of Illinois (16)
6. A Computer Program for Budget Forecasting, Harvey Mudd College (17)

These programs are introduced here to give the reader an indication of the scope of the programs that are already available to aid decision-making in higher education.

Another large class of inputs to the decision rules of an educational institution consists of the administrative policies of the school. These are policies related to such items as personnel relations, public relations, finances, campus maintenance and operations, planning and development. These policies vary from school to school, department to department, administrator to administrator. Often, policies are formalized in faculty handbooks, administrative codes and committee minutes; but usually, they are contained in the minds of the people who are doing the work. As yet, few formalized procedures have been developed for systematically and economically gathering and compiling policy information so that it can be readily used in systems analyses and computer simulation of the educational system. The most significant input to the decision rules in an educational system, however, is the curriculum.

The Curriculum: A major input to decision-making

The curriculum, educational program, or program of study reflects the purposes and educational objectives of the school. It delineates in what ways the student population is to be transformed while passing through the educational system. Hence, it is concerned with the education process; what is to be taught, how much, when, where, and how subject matter is to be transmitted. Curriculum synthesis implications constitute primary inputs to the decision rules which control the data processing and ultimately the operations of the entire educational system. Decisions regarding the allocation of faculty, staff, facilities, equipment, and services flow directly from a knowledge of the requirements of the curriculum.

In order to consider some of the research that recently has been carried on in the area of curriculum, this area will be divided conceptually into two parts; the curriculum content allocation and the curriculum content transmission. These two parts form an iterative loop as shown in Figure 1. Studies are made to determine what and when subject matter should be taught, then the teaching methods are studied, then original assumptions regarding time allocations to the subject matter are reexamined and revised, then the teaching methods are improved, and so forth. At any instant in time, the data regarding the current status of our knowledge of the curriculum can be tapped off from the iterative loop and supplied to the decision-making component of the system.

A comprehensive review of the literature on curriculum planning and development during the period of time between June 1960 and June 1963 is presented in the Review of Educational Research (18). Most of the literature reviewed was written by persons who are engaged in research in education, psychology, and related fields. The following section will indicate some of the recent research in the area of curriculum which has been conducted by persons with mathematical and/or engineering orientations.

Curriculum content transmission

The emphasis in curriculum content transmission has shifted in recent years from research on conventional teaching methods, through programmed textbooks and simple mechanical teaching machines, to computer-based instruction. John E. Coulson, at System Development Corporation, has pointed out that a few controlled experiments with computer-based teaching systems, while encouraging, have not yet demonstrated clear-cut superiority of this method of instruction over simpler, more orthodox teaching methods (19). In addition to research and development of learning laboratories, special mechanical teaching and communication devices, and time-sharing computer systems, programmed learning has led to basic research in learning theory.

A considerable amount of attention has been focused upon optimum methods of presenting instructional items to the student (20). Programmed instruction has dealt largely with linear (fixed sequence) programs and with branching programs (scramble books) which offer the student alternative paths or item sequences through the lesson (21). James E. Matheson, at Stanford University (22), has studied the teaching of a list of paired-associate items in a fixed number of presentations. He assumed the validity of the simple learning model of Atkinson and Estes (23), formulated a reward structure in order to measure the effectiveness of teaching, and in terms of the reward structure and the learning model he derived optimum teaching procedures by applying dynamic programming techniques to

Markov processes. It is usually assumed that the state of the Markov process is directly observable at each step in the process. It is then possible to base all decisions about the process upon the state of the Markov process without regard to the past history of the process. But the state of the Markov learning model is not directly observable, and those observations that are available depend upon the state of the model in a probabilistic manner. Matheson (22) derived an equivalent Markov process in the observable states of history and then treated this new process by conventional means in order to optimize it.

In his engineering doctoral dissertation, Arnold Roe (24) developed an analytical adaptive decision structure for educational systems. His decision structure rested upon four cornerstones: a plan for gathering and using data; an explicit criterion function; a set of decision rules for achieving the criterion; and a utility function which relates system inputs and system outputs to a value scale outside of the system. The utility function defines the output of an educational system as the increment in life-cycle productive output attributable to the educational experience for all individuals who have been part of the system. It provides a means for converting such available measures as student grades, student learning time, teacher inputs, school capital and maintenance costs, and so forth into a net value of the transformation effected by the system. The suggested criterion function which must be maximized is the sum of the net utility of all students' outputs. Roe also developed decision rules which tend to maximize the criterion function under different conditions of a priori information. This research led to the development of a computational backwards-induction solution for the multi-stage or continuous sampling procedure from normal populations.

The objective here is not to discuss the merits, assumptions, or implications of the foregoing research but, rather, to indicate the type and scope of recent research efforts in the field of education by people who have mathematical systems-analytic orientations. The two references just cited contain extensive bibliographies of other recent research projects in this field.

Curriculum Content Allocation

The curriculum content allocation is related to which items we should teach; how much time should we spend on each one of those items; and how we should divide up the time that we do allocate to each item over the entire time the student is in school. There are some interesting innovations that have been developed in recent years in answer to these three questions.

The methodologies that I will describe presuppose that the faculty and administration have reached some consensus regarding the needs of the community, school objectives, desirable characteristics of the entering and graduating student, and general system constraints. Time does not permit discussion of how this may be accomplished but there are systematic methods available. I would like to start from the point at which such decisions have already been made in the design and redesign of the engineering curriculum at UCLA. It was found that the design of anything whether it be a mechanical device, a business, a bridge and even a curriculum involves a specific set of design steps.

The procedure, while varying in words from one type of design item to another, essentially says that one must identify the needs, gather information regarding the organization and such data that is available. There must be some identification, modeling and analysis of the system variables, and constraints. Some criteria must be set up by which you can judge whether you are moving ahead or moving backwards in your design; namely, you must set up some kind of value system. Then you must synethesize various possible solutions. Hopefully, as a next step, there will be some optimization of whatever you have designed. You might go through some testing and evaluation and prediction of performance both from the theoretical and ultimately from an empirical standpoint, and finally, there is a process of iteration which involves going back to any one of the preceding steps and reevaluating assumptions and procedures that were carried out. It is expected that this type of a feedback system yields an improved design as one proceeds step by step.

The engineering faculty at UCLA decided that the design of the curriculum is certainly amenable to this kind of a procedure and they addressed themselves to the question of gathering information and determining what is already known about the curriculum. What is known about the curriculum is in the school catalog. It states which courses are being offered, but this was not a sufficient description upon which to decide which items to put in and which items to leave out. Therefore, a specific procedure was evolved whereby each course could be broken down into very much smaller items or topics. In the case of engineering, each course could be broken into what was called descriptors. Now a descriptor might be a law, concept, precept, definition, a method or mode of analysis or synthesis. It could also be a skill, a tool, some factual data or some kind of application.

Each faculty member was given a mimeographed form on which there was space for him to write all the principles, laws, concepts, precepts, etc., that are given in the courses that he teaches. Each one of the descriptors was very carefully defined in order to reduce ambiguities. When all of the forms were returned each item was typed on an IBM card and the number of items in the engineering curriculum which included math and physics amounted to about 4,000. These were then sorted in accordance with special requirements of the faculty. For instance, the items were sorted according to all of the definitions, precepts, concepts, and so on, and it was found for instance that after repetitions were removed that there were only 15 principles in the four year engineering curriculum. There were a great many more laws, concepts, skills, applications and so forth.

The items could also be arranged alphabetically. They could be arranged according to any other type of grouping to form topics which go together. Thus, a number of descriptors in physics could be put together to form a new type of course. Each item could serve as a different type of a descriptor in different courses. Thus, statistics was an item which could be a method of analysis and synthesis in one course, a definition in another, a concept in the third course, a tool in the fourth course and a skill in still other courses. In this way it is seen that the item of statistics can be approached from many different viewpoints and that this fact was certainly true in the existing UCLA curriculum.

By means of this straight forward procedure all of the items in the curriculu can be presented according to descriptor, according to specific areas of interest, with complete alphabetical index with cross references, and in numerous other ways There are many uses for an index of the curriculum such as this. Such an index ca provide an up-to-date reference system for all items in an entire curriculum which for example, provide detailed knowledge about each course and its prerequisites, facilitates standardization of multisection courses and the synthesis of new courses. Finally, the index can serve as a model for other disciplines to undertake similar analyses of their own curricula (25). This is of course what I am suggesting here.

We must now look to a set of rules which will efficiently organize the aforementioned material. Basically, what is required is a systematic procedure for determining which items shall be kept in the curriculum and which ones shall be discarded, and of those that are kept, how much time during the entire four years the student is in school shall be allocated to that item. The engineering schools at UCLA and at Dartmouth solved this problem by setting up specific criteria by which to judge whether an item should be kept or discarded. There are three such criteria.

The first one is called the Criterion of Relevance. An item is to be kept if it was very relevant to the objectives or the rationales of the curriculum. This implies that there are some items that are in fact so relevant to the objectives of the curriculum that if we would leave them out we could never achieve the goals or the aims. Those items are 100% relevant. All other items which are somewhat less relevant have a decreasing order of priority and would be given less time or weighted less.

The second criterion is the Criterion of Generality. The generality of a subject is measured by the number of other subjects that it serves. The more subjects that an item serves or the more courses in which an item is used, the more general that item is and the greater is the probability and desirability of maintaining that item in the curriculum and giving it more time.

And finally the third criterion is that of articulation. We tend to select subjects or items which will offer additional and useful curriculum redundancy by using the knowledge previously imparted in other subjects. This criterion is really redundant. It means that we will repeat material that we have already presented in other areas and some items which depend upon many other items or topics that come before this. In a sense, prerequisites are very important from a learning standpoint in that a student must master them if he is to assimilate the new information presented to him. At UCLA, under the direction of Alan Rosenstein, a mathematical curriculum model has been developed along with an optimization procedure to effectively utilize the above criteria. The criteria of relevance, generality, and articulation are employed as weighting factors in allocating time to each item.

This procedure provides a logical and efficient means for choosing among contending items. It is reasonably clear that, even with the aid of a large sized computer, to handle the mathematics involving 4,000 or so individual items can constitute a very large problem. On the other hand it is also clear that many of the items can be combined to form topics and the topics can be combined to form stems, namely, major categories of subject matter.

It now becomes apparent that we can apply the curriculum synthesis procedure or the allocation procedure to allocate the amount of time to be given to each one of the stems. If desired, each of the stems can be broken down into topics. It all depends upon the time, resources and inclination of the faculty and administration in a given school. The methodology is quite general in this respect. The power of this methodology stems not only from the broad staff participation that can be obtained in the original curriculum synthesis, but also from the ease in which the curriculum can be currently maintained with a very nominal staff effort. Successful application of the procedures could eliminate expensive and exhaustive efforts now required nearly every five years to rebuild curricula that have become obsolete. The opportunity exists for the creation and maintenance of truly viable curricula.

The third area that I would like to touch on briefly is one that I have worked on personally for the last two or three years and the problem that I pose here is one of how to distribute the time that the faculty has allocated to a given topic or item or course (26). If you decide to spend twenty hours on first Law of Thermodynamics for example, should you teach it all in the first semester or should you teach three hours the first semester, four the third semester, and six hours the fifth semester, and so forth. If you decide to distribute the hours or even to present the material all at once, is there an optimum way in which you can distribute or schedule each one of the items or courses so that on the day the student graduates he will have maximum mastery over all of the material to which he has been exposed.

Probably the easiest way to recognize the complexity of the question I have just posed is to consider the case of a student coming from some junior college into the junior year of an engineering curriculum. The student might be taking four or five courses each one of the semesters in his junior and senior years. Let us consider just one course in each semester to simplify things although he would simultaneously be taking more than one. The following discussion is shown in Figure 2.

In the junior year the student might be taking a course in Electric Circuits and as you recall from learning theory as a student learns his knowledge will rise slowly at first and then increasingly more rapidly as he gets more experience behind him in the course. And finally at the time he ends the course he will have reached some level of mastery of the material of the course and we give some examinations to determine some relative number for how much a student knows about what was presented to him in this particular course. Now if the student stops studying at the end of the course and has let's say two weeks of intersession then he will forget a little bit. If you gave a test, he would not remember as much as on the day he took the final exam. If in the next semester, let us say in the spring semester, he were to use one or two of the topics from Electric Circuits in his Thermodynamics Course or in some other course he is taking, then that material would be reinforced and his knowledge would rise again in the Electric Circuit Course. Then, if he never used that material again in any of his other courses until graduation his knowledge would constantly decay until the day of graduation an estimate of the students knowledge in Electrical Circuits would be given by some amount shown on this graph.

On the other hand the following semester in the spring semester if the student were to start taking Thermodynamics his knowledge would rise; then if he would not use it during the summer time his knowledge would drop. If it were reinforced in some other course it would rise again and fall again and rise again until on the day of graduation he will remember a certain amount about the course. He will have some level of mastery about the course relative to what he knew when he started. In using our knowledge about the principles developed in learning theory from psychology and education, I have developed a mathematical function which generates the curves which you see in Figure 2.

Shapes of the curves depend upon a number of very important basic variables. These include the type of learner, the type of teaching methods, type of subject matter, the cumulative amount of time that the subject has been taught, the cumulative amount of time that the student has had to forget the material and the number of repetitions of the subject matter in various courses and within courses. If we can estimate the students level of mastery in any one particular course, then we can make some kind of estimate of his level of mastery in all the courses he takes and if we add together his total level of mastery in all the courses on the day of graduation or the day he leaves we will have some level of indication of the effectiveness of the particular schedule or program of study.

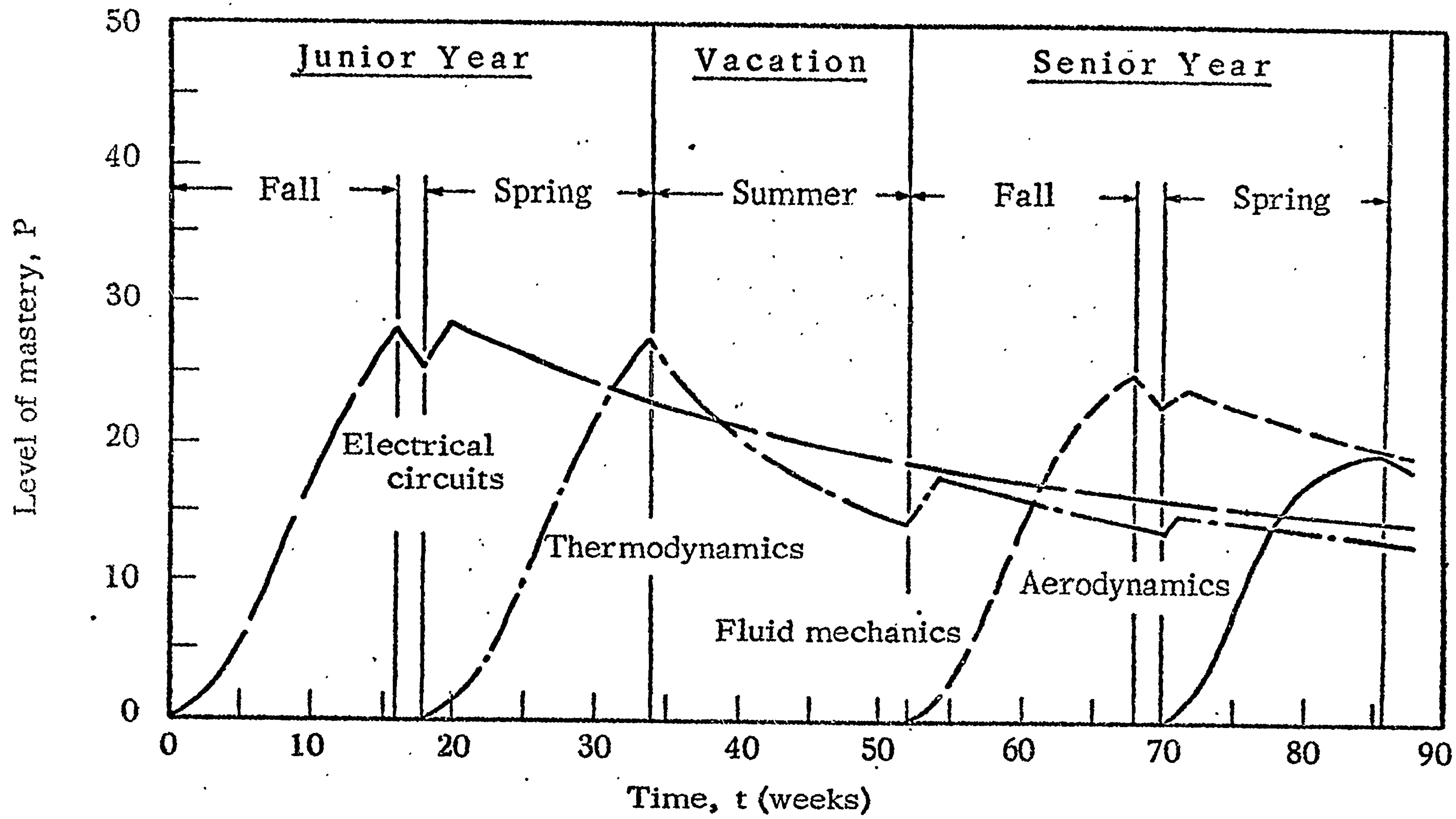


Fig. 2. --Levels of mastery as function of time for four courses in Engineering at California State College at Los Angeles. (Computer computations were based upon typical catalog schedule and current college requirements and constraints.)

Thus as an example (see Figure 3) if we thought of Courses A, B, C, and D taken initially in the sequence I just mentioned, we can see that if we add up how much the student knows at the end for each one of the courses we might obtain a number like 22.9. However, if we juggle the courses around and put A before B, C before A, and so forth, we would get a different schedule and because of the difference of reinforcements of one course by another the total level of mastery for the new schedule will be quite different from that in the initial schedule. Thus, I have developed a heuristic algorithm (namely, a rule of thumb procedure) which finds not necessarily the very best schedule, but at least a much better one than we have now,and it does this by going through a procedure whereby each course is exchanged in location with every other course in the curriculum and the total level of mastery for each one of the schedules is compared with the previous one. Only the better schedule is retained in the memory of the computer and finally, when no improvement in schedule can be obtained, the program stops. We have found the best schedule.

As you can see in this very simple case the best optimum or suboptimum schedule is the one in which Course C comes first then B then A then D. By putting Course C before Course A, the student's knowledge in Course C reaches a higher level due to reinforcement by Course B. Similarly Course A has the possibility of reinforcement by Course D. And so the final amount that the student might know at the end might be 32.2 rather than 22.9.

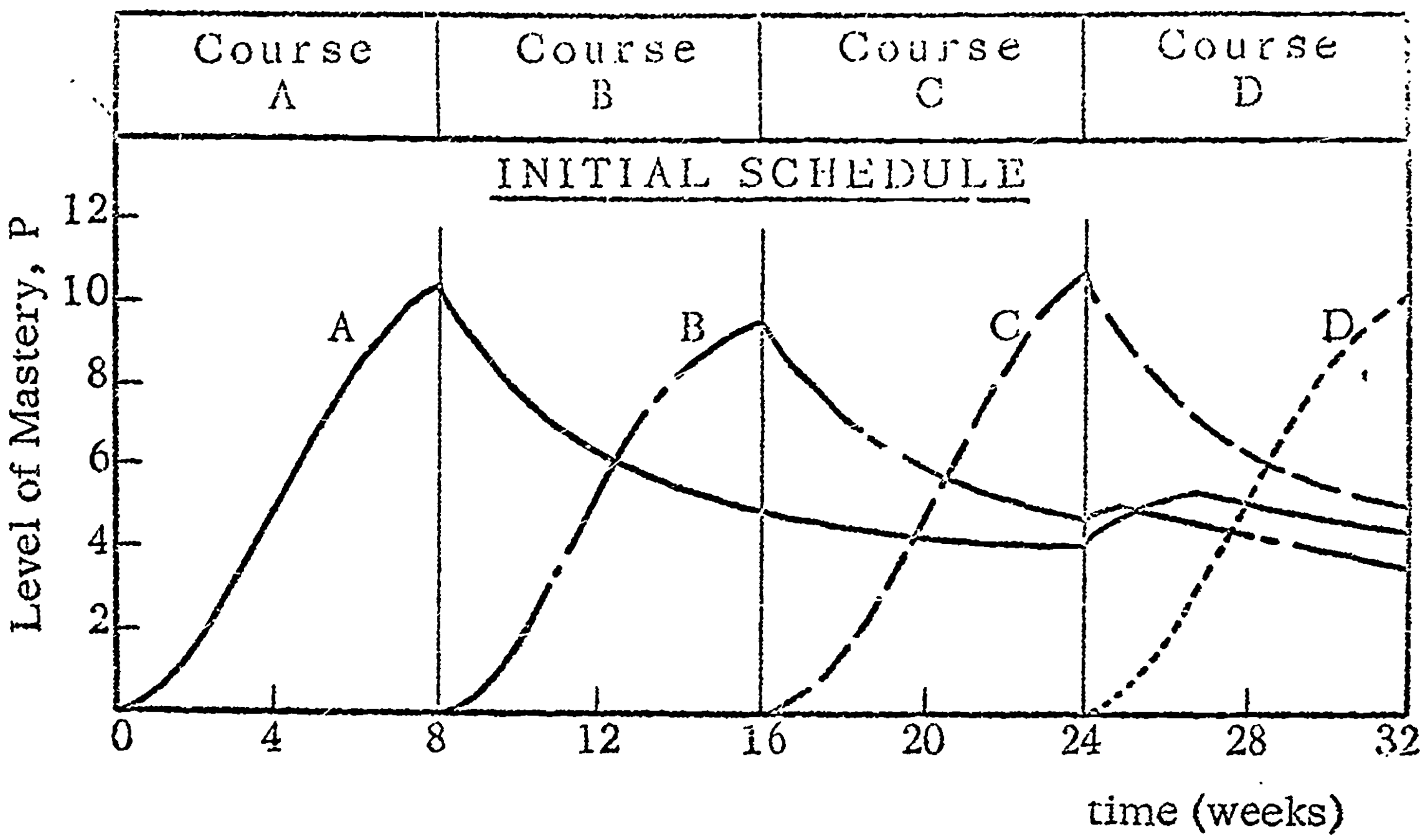
Although this model suffers from the major limitations of any model; namely, that it represents only a very crude approximation to what exists in reality, it offers one of the major advantages of any model. As empirical data is gathered the model can be slowly transformed and improved and can ultimately be made to approximate reality to a much greater extent than it does at the outset. Futhermore, the model offers a unified approach to curriculum planning. It integrates the usual logical and time constraints on the curriculum content with our broad existing knowledge about educational psychology. It allows us to make the learner or the student an integral input to the curriculum planning. It focuses attention on the major variables connected with curriculum research and offers a particular functional relationship between these variables.

The model's greatest significance lies perhaps in the fact that it presents an explicit conceptual framework which can be tested, verified, improved or even rejected. The framework represents a rather detailed blueprint for action. It encourages the use of simulation, heuristics, and statistical teahniques to deepen and integrate our knowledge in such specialized areas as learning theory, curriculum synthesis, student counseling and testing.

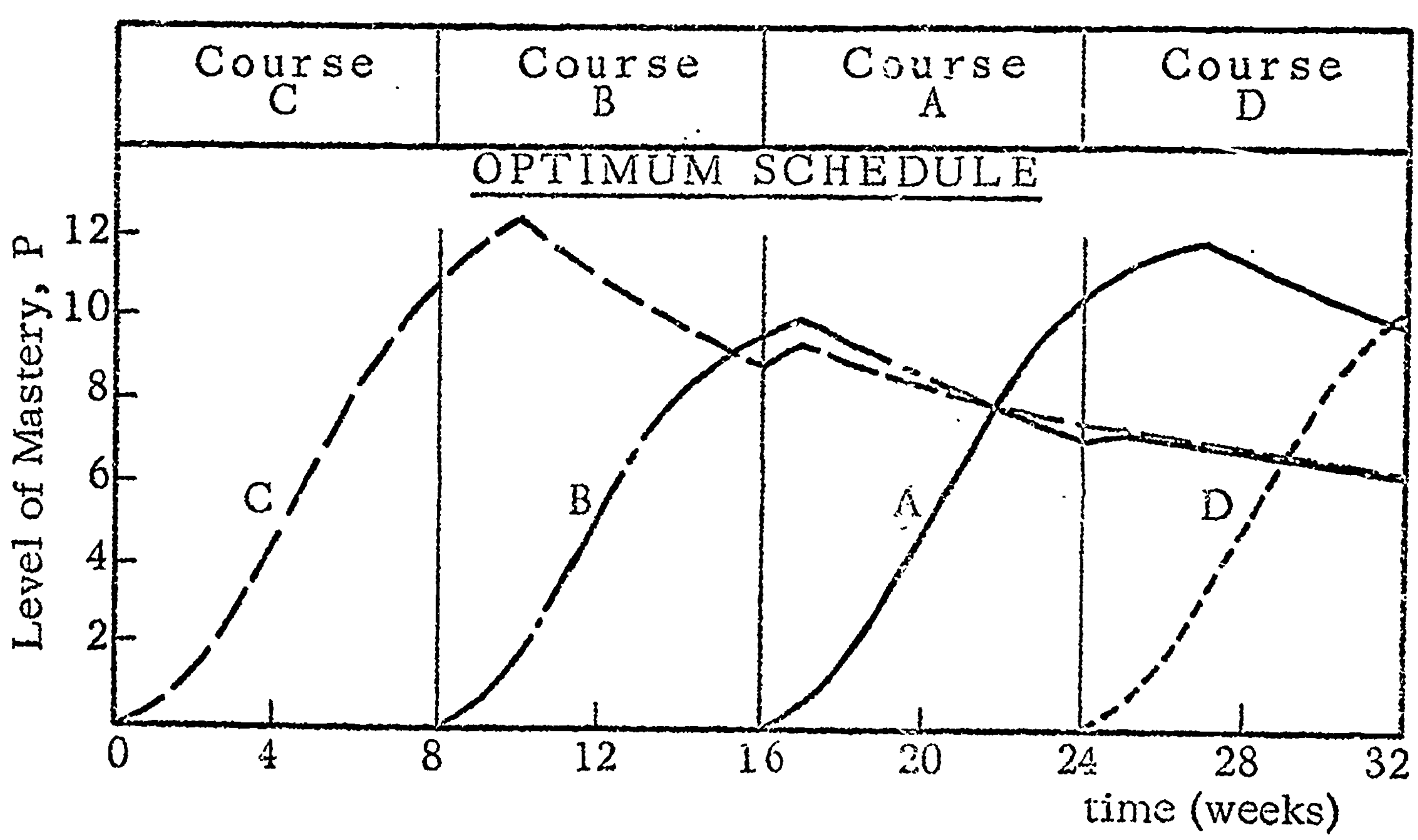
Last year, we attempted to develop programs which would implement this model at Cal State L.A. Some of these involved the School of Education and our training programs for teachers; some of these programs involve our freshmen class; and some of the programs involve individualized counseling.

This year, at the University of Wisconsin-Milwaukee, we are developing these ideas further and are proposing to test them at the new high school which will be built in the Arrowhead Unified School District, Hartland, Wisconsin. Many of the planning, curriculum, financial, and evaluation models that I have been developing over the years, in collaboration with my good friend and colleague, Dr. Arnold Reisman, will be further developed and tried out both at the high school and at the university levels.

In conclusion I would say that systematic tools for analysis and synthesis in the area of curriculum are already available and it only requires initiative and perseverancefor their implementation.



$$P_i = \sum p = p_A + p_B + p_C + p_D = 22.9$$



$$P_o = \sum p = p_A + p_B + p_C + p_D = 32.2$$

Fig. 3--Increase in level of mastery due to sequence changes of subject matter.

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