SIMULATION ANALYSIS OF A MODEL FOR PLANNING THE TRANSFORMATION OF AN EDUCATIONAL SYSTEM FROM A CONVENTIONAL INTO A TELE-EDUCATION SCHEME

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A Thesis

in

The Department

of

Education

Presented in Partial Fulfillment of the Requirements for the Degree of Master of Arts (Educational Technology) at Concordia University Montreal, Quebec, Canada

December, 1980

ABSTRACT

SIMULATION ANALYSIS OF A MODEL FOR PLANNING THE TRANSFORMATION OF AN EDUCATIONAL SYSTEM FROM A CONVENTIONAL INTO A TELE-EDUCATION SCHEME

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Tele-education is the provision of education based on self-instruction, including distance study systems. This thesis is intended to provide educational technologists with a model for transforming already existing systems into systems of tele-education. Using a systems approach, the model assists the educational systems planner to produce alternative plans for the transformation. Steps include: instructional analysis of courses offered in order to determine what materials need to be developed for each course; expressing this information in a "preferred" media-mix matrix; determining costs of producing the materials needed; optimization (if necessary) of instructional and budgetary constraints under different conditions and, according to the results, reassigning the media-mix matrix; and determining (if applicable) requirements that the Learning Resources Center should meet at "end-state" situation under each alternative plan. A set of simulations was run to compare the outputs of the model under different inputs. Data from an educational system (the Graduate Programme in Educational Technology at Concordia University) were used to test the model. Findings, recommendations, and suggestions for further development are submitted.

ACKNOWLEDGEMENTS

I am deeply grateful to all those people who made the writing of this thesis a learning process full of rich and pleasant experiences: Dr. P. David Mitchell, for his encouragement, direction, and always pertinent advice; Drs. Gary M. Boyd and Richard F. Schmid, for their critical feedback that proved to be essential to this endeavour; and finally, to Marylee Brassard, Laura Winer, and my wife Lourdes, from whom I received much intellectual stimulation and help. This thesis indeed reflects to a large extent some of the much I have received from all of them; and it is my pleasure to say that it would hardly have been written without their concerned participation.

A la memoria de mis maestros Manuel Alvarez-Ugena,

Juan De Oyarzabal y Jesus Vazquez Gayoso.

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CHAPTER 1: INTRODUCTION

THE EDUCATIONAL TECHNOLOGIST AS INNOVATOR

The educational technologist is a professional dealing with a variety of problems in the field of education. The practice of educational technology has been described by Mitchell (1978) as "concerned with all aspects of the design and optimal organization of educational systems and subsystems and with the relation between their inputs and outputs, between desired outcomes and the allocation of resources to achieve them." (p.331) The intrinsic complexity of the problems that the educational technologist has to face must be realized in order to understand the difficulty of the task implied in the previous statement.

If innovation is a planned change in a system (Morrish, 1976, p.11) then the educational technologist is a professional concerned with educational innovation. Educational systems, and more precisely the institution of School, have always been conservative systems seeking to maintain and to mediate the cultural inheritance of society. However, education's role cannot be a static one because, at least as regards its economic development, society requires a dynamic role from education: to the static character of the transmission and wide dissemination of knowledge and skills, educational systems have to add the capacity to develop the essential research for the evolution and transformation of society (Groves, 1963).

The dual role imposed on education, the zealous keeper and the sower of change, is certainly reflected in the practice of educational technology. The practitioner in this field is aware of the need for change in educational systems; that they are, as any other subsystem of society is, subject to the inexorable law of "change or perish." But it is also true that professionals in education are generally reluctant to change. This constitutes the main reason why educational systems are agents of conservation (Bereday, 1969, p.93) and why general change in education is a long term process (Morrish, 1976, p.23). Educational technologists, thus, must be aware of the inertia of the system they are dealing with.

The role of educational technologists is both difficult and challenging. The success of the innovations proposed by them depends on factors that are extrinsic as well as intrinsic to their capabilities. It is essential for them to gather information in order to maximize their knowledge about the system under consideration. This task implies not only the search of available data but more often the design and carrying out of research to obtain essential knowledge. More importantly, they must also be able to reduce the information available to a manageable and useful amount while retaining enough to provide them with requisite variety. To say it in Ackoff's words, the innovator needs wisdom, "the ability to see the long-run consequences of current actions, the willingness to sacrifice short-run gains for larger long-run benefits, and the ability to control what is controllable and not to fret over what is not." (Ackoff, 1970, p.1)

Wisdom and the ability to gather relevant information must be intertwined with the technical knowledge necessary to produce optimized models for innovation, models which prove to be pertinent, relevant, and feasible with regards to the system under study. But if the practice of educational technology is to become successful, practitioners must be knowledgeable on educational grounds because, first and foremost, they must be researchers in education. Convincing the conflicting parts of the system involved of the importance of the innovation proposed is not merely a result of superior rhetoric, but also a function of the soundness of the proposals developed.

- THE FEASIBILITY OF AN INNOVATION

The feasibility of an innovation, as was pointed out earlier, is a two-sided issue. First there is the political feasibility, seldom dependent on factors under the innovator's control (and thus not amenable to an objective and systematic analysis). The technical feasibility, on the other hand, is concerned more with problems like the optimal allocation of human and material resources. This concern can be better described as a scientific and systematic attempt to avoid doing wrong things and, at the same time, to do right things efficiently. Certainly, the political feasibility would rank higher than the technical one should a hierarchy be considered: the best technical effort will not make feasible a politically unfeasible innovation. However, a politically feasible innovation that lacks technical feasibility could only lead to an inefficient implementation if not to plain failure. Technical feasibility is a necessary but not sufficient condition for an innovation's successful implementation. However, it is my point of view that it is an integral part of the educational technologist's role to provide educational innovations that fulfill this condition.

- ET AND THE TRANSFORMATION OF EDUCATIONAL SYSTEMS: THE ALTERNATIVE OF TELE-EDUCATION

The transformation of an educational system is one of the most demanding problems that an educational innovator can face.

The fact that most people living in the world today have not had educational opportunities should not only be "morally repugnant to the educational researcher" (Mitchell, 1974), but is a situation that no society can allow, if for no other reason than the fact that no economic development can afford to have a significant part of its labour force uneducated. In addition, no country in the world can provide the education its population needs by schooling alone (Gerin-Lajoie, 1971; Erdos, 1976). The transformation of the school into a broader educational system concerned with many aspects of education, as well as featuring innovative ways of organizing it, is already a necessity. The role of educational technologists in this transformation should be a principal one because they may be one of the few professionals aware of the need for this innovation as well as the only ones with the adequate knowledge and skills to undertake it.

One possible way of coping with this problem is the transformation of traditionally school-based educational systems into systems of distance education. Distance education has been defined as:

> a form of education where verbal instruction is limited in quantity and is confined to a number of intensive periods spread out during the term or

> the academic year. Between these periods the student works on his own but can consult teachers by telephone or by post (Willen, 1975, p.1).

It is generally accepted that distance education had its roots in the correspondence courses that flourished after the first half of the last century (Rawson-Jones, 1973). Although originally limited to vocational subjects, distant-study and correspondence courses are today offered by private schools, industries, government agencies, and universities in virtually any field from the elementary level to the postgraduate level (Encyclopaedia Britannica, 1980).

It has been recognized that two-way communication is an integral element of distance education (Rawson-Jones, 1973). This recognition is inferred from the importance of feedback channels and interaction in any educational process. A variety of approaches to providing two-way communication in distance education systems have been proposed (cf., Flinck, 1975; Harris, 1975; Lampikoski, 1975; Perraton, 1975). As well, reports are available that study the relative effectiveness of different modes of two-way communication (eg, concerning telephone usage see Daniel and Turok, 1975, and Flinck, 1978). Thus, a better definition of distance education would not stress the lack of permanent personal contact between learner and instructor as a feature of distant study systems. Rather, this reduction in contact time is a consequence of the implementation of a general policy in order to achieve a high-priority goal: offering educational opportunities to learners for which conventional schemes are not suitable due to constraints of time and/or distance. As Lamacraft has stated, "distance education owes its existence to the economic and social impracticability of providing opportunities for attendance education for all those who are required or who wish to learn" (Lamacraft, 1975, p.42). Thus, a more satisfactory definition of distance education is the one found in Daniel and Stroud:

> Distance education describes situations where teachers and learners carry out their essential tasks apart from one another although they communicate in a variety of ways. The fundamental purpose of this approach is to make education more openly and widely available by freeing students from constraints of time and geographic distance (Daniel and Stroud, 1980).

As in any educational system, the role of media in distant study systems is a principal one. In this thesis a broad definition of educational media (like the one by Gagne, 1969) will be adopted: they are those components of the learning situation which stimulate the learners - in other words, which communicate with them. According to Kozma et al (1980) educational media can be divided as regards communication flow into three categories: one-way, two-way or interactive, and self-instructional media.

> One-way, or presentational, media such as lectures, films, televised instruction, books, and demostrations are characterized by a flow of information from the instructor to the student without reciprocity. When these media are employed, the student has little or no opportunity to influence the instructor or to change the message....two-way, or interactive, media such as discussions, games, tutoring, and role plays are reciprocal. Although they are not as efficient as presentational media in transmitting information, they do allow the student to play an active part in learning....to these two categories can be added a third class of media -- self-instructional media, which include programmed instruction, personalized instruction, audio-tutorial instruction, and contract learning. While similar to two-way media in being interactive, these types of media tend to be more structured...[they] allow a student to proceed with learning at his own pace and with his own interests,

> independent of immediate instructional supervision. They do, however, require a great deal of planning on the part of the instructor, who must create materials and arrange for other supporting resources (Kozma et al, 1978, pp. 52-53).

As compared to distance education, tele-education, in its broadest sense, is the provision of education based on self-instruction (Mitchell, 1980). Accordingly, a system of tele-education will use primarily, but not exclusively, interactive and self-instructional media. Thus a distant study system such as a correspondence course is an example of a tele-education system.

However, tele-education is not restricted to distance education. It is not necessary to have a physical distance between the student and the instructor to talk of tele-education. This erroneous implication is what Rawson-Jones disliked in the term 'distance education', that "it seems to put an undue emphasis on the distance between the teacher and the learner, but I cannot think of a better name for a multi-media educational process in which the teacher and the student may never meet in a face-to-face situation" (Rawson-Jones, 1973). Self-instruction may well be provided in a Learning Resources Centre, either within the physical structures of an educational institution or outside of them. For example, a department within a university that offers courses or parts of them through modules in an LRC would be practicing tele-education. One example of a tele-education development to meet the educational needs in a developing country is found in the Mexican Tele-secundaria. The Mexican Government had available material resources (rooms, broadcasting hours allocated on commercial TV networks, etc) but a shortage of secondary school teachers made it difficult to offer secondary education in many areas of the country. In the 1960's a solution was found to partially alleviate this problem: a small team of secondary school teachers was hired to develop and broadcast classes, while "monitors" (usually primary school teachers) would direct the activities in the classrooms, mainly selecting the channel on the TV set, directing the discussions afterwards, and collecting classroom and home assignments. Besides watching the TV programs (all programmed by the planning team), instructional activities relied heavily on students' own work. Tele-secundaria proved to be a modest, but highly cost-effective, tele-education development (Jamison, 1977; Jamison et al, 1978).

Planning, designing, and starting an educational system as a tele-education one is a task that has already been undertaken numerous times (concerning UK's Open University, cf. Perry, 1975; McIntosh et al, 1977; Hawkridge, 1978; Harrison, 1980. For a discussion of the small transfer value the OU model has for other situations, cf. Mitchell, 1980). But the need for educational systems featuring this new type of organization cannot be dealt with only by creating systems planned to follow this alternative from their inception. More important, and certainly more difficult, is the task of transforming already existing systems into different organizations, ready to face the future and to deal with the problems already critical: "The consulting educational engineer is not so likely to be asked to design an open university as he is to transform an existing organization into something more efficient or more effective" (Mitchell, 1980, p.9:4).

This thesis is intended to provide educational technologists, in their role as educational systems analysts (Mitchell, 1975), with a possible framework and a methodology for undertaking such a transformation.

- THE RELEVANCE OF MODEL BUILDING AND SIMULATIONS FOR PLANNING AN INNOVATION

> No substantial part of the universe is so simple that it can be grasped and controlled without abstraction. Abstraction consists in replacing the part of the universe under

> consideration by a model of similar but simpler structure. Models...are thus a central necessity of scientific procedure (Rosenblueth and Wiener, 1945, p.316)

Model building and simulation are integral to the planning of educational innovations, as they are in any systems analysis and/or planning activities. Briefly, simulation is a technique that involves setting up a model of a real situation and then performing experiments on the model. In a more restricted sense, computer simulation is a numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical models that describe the behavior of a system, or some components thereof, over extended periods of time (Naylor et al, 1968). As for what is meant by a model, "[although] the most common meaning of the term 'model' found in the vernacular is the reference to the simulation of the physical appearance of an object...a more relevant meaning...is duplication of the operating principles of a system" (Levine and Burke, 1972, p.6). Thus, the statement of Rosenblueth and Wiener above may be extended to say that a scientific model is an abstraction of some real system that can be ultimately used for purposes of prediction and control. The purpose of a scientific model is to enable the analyst to determine how one or more changes in aspects of a modelled system may affect other aspects of the system or the system as a whole (Naylor et al, 1968).

The technical feasibility of an innovation, as was stated before, relies in the use the system analyst or planner makes of the scientific method in his/her undertakings. The scientific method has been summarized (Naylor et al, 1968, p.5) as follows:

1) Observation of a physical system

2) Formulation of a hypothesis (or a mathematical model) that attempts to explain the observations of the system

3) Prediction of the behavior of the system on the basis of the hypothesis by using mathematical (or logical) deduction, ie, by obtaining solutions to the mathematical model or models

4) Performance of experiments to test the validity of the hypotheses or mathematical model

However, sometimes it is simply not possible to follow all of the steps outlined above for a particular problem or system. When this is the case, some form of simulation may be a satisfactory substitute for the step (or steps) above which is causing the difficulty. First, it may be either impossible or extremely costly to observe certain processes in the real world. Second, the observed system may be so complex that it is impossible to describe it in terms of a set of mathematical equations for which it is possible to obtain analytic solutions which could be used for predictive purposes. Third, even though a mathematical model can be formulated to describe some system of interest, it may not be possible to obtain a solution in the model by straightforward analytical techniques, and in turn make predictions about the future behavior of the system. Finally, it may be either impossible or very costly to perform validating experiments on the mathematical models describing the system. Simulated data can then be used to test alternative hypotheses concerning the future behavior of the system (Naylor et al, 1968).

On the other hand, simulations are also a powerful tool when the engineering of a system, as oposed to simply prediction, is involved. An example of this application can be found in the systems engineering approach to the design of an innovation, where simulations can be used to plan system's end-state (ie, "end" of a sequence of controlled transformations) and then to work backward to determine what intermediate states or decisions or inputs are needed to produce it.

The relevance of simulations to studying the problem under consideration should now be appearent. It is certainly very difficult to observe the transformation process of an educational system. In this thesis my concern is to promote that process and give it a specific direction by taking a particular educational system from a precise starting point towards a specific desired state; ie, from a conventional to a tele-education system. Observations may be made on systems that appear similar in situations that may resemble the one of interest; however, the combination of a specific system and innovation makes the process so unique that the value of conclusions obtained from observations of other processes is minimized when compared to what is derived from a simulation.

It is generally true for societal systems like educational ones that once a process has started the system will never recover its initial state; or, in other words, that societal systems always undergo dynamic processes. Thus, the only way to predict a system's future behavior under different innovative conditions, and the only way to perform experiments validating the hypotheses underlying each alternative, is by means of a simulation.

CHAPTER 2: OBJECTIVES OF THIS THESIS

This thesis offers an explanation and analysis of a technically feasible course of action for transforming an educational system operating under a conventional scheme into a tele-education system.

The main focus is placed on the initial step, once the intention to start the transformation has been stated. What then are the assumptions and constraints that the educational technologist has to consider in order to produce a technically feasible plan for this undertaking?

Sufficient funds are seldom made available for an "ideal" transformation to take place. For example, some particular media may have production requirements which are so high in terms of time and/or money that they render the whole plan unfeasible.

It is possible to translate budgetary constraints and educators' requirements into a mathematical model, and then to discern what modifications to the educators' preferences could be suggested in order to obtain a starting framework for a feasible and optimized plan. Feasibility here means respecting educational and budgetary constraints; optimization refers to either minimization of costs or maximization of educators' requirements met, within the given constraints.

This thesis sets up an initial framework for planning the transformation. It is concerned with the system as a whole and not only with the microenvironment. That is, it does not address the problem of a single instructor wanting to change a course into a distant study course asking for an "optimal" way of making this transformation. Rather, the concern is focused on the transformation of an educational system, composed of several such microenvironments, into a tele-education system. As well, this thesis is concerned only with planning the first step for an innovation. That is, it deals with starting budgets and instructional material production (as opposed to reproduction) costs; and it outputs a set of parameters to be used in the implementation of the initial step. It often happens that an organization embarks on the implementation of a plan without having discussed many details and implications of it. Were it just for the help it gives in clarifying these points before implementation is undertaken, the procedure suggested here would have a great value for systems analysts. But it also serves as a framework within which to negotiate the trade-offs between budgetary constraints and educators' preferences. Used as a simulation model, the effects of changing some parameters can be studied not only for their implications on plan's feasibility, but also for comparisons (eg cost-effectiveness type of analysis) between different optimal solutions corresponding to (input) situations.

The presentation takes on the form of a paradigm, but the assumptions made concerning the initial conditions of the system are so general that they would fit most situations. The method outlined could be easily adapted and implemented, at least as a starting point from which to undertake the task of transforming a system.

CHAPTER 3: IDENTIFICATION OF THE PROBLEM

Let us consider an educational system which is organized to offer a number of one-term courses (multi-term courses may be considered as the equivalent number of one-term courses). Each course is given a number of credits reflecting the amount of time the student is supposed to spend doing course-work; eg, a 3-credit course would require a total of 135 hours of student's time in course-work on the basis of 45 hours per credit.

This educational system operates according to a conventional scheme; that is, each course is lectured by a professor and students have to attend the lectures, as they constitute the primary source of information about course contents and requirements. There is, roughly speaking, one hour of lecture per five hours of student's course-work time.

Given some specific (budgetary) constraints, is it possible to develop a model whereby:

A) a feasible (optimized) plan to achieve the tranformation of this educational system into a tele-education system can be deduced, and

B) the effects of changes in some parameters on the plan's feasibility can be studied, in order to analyze the cost-effectiveness of different input situations?

CHAPTER 4: THE MODEL

The model offered in this work was first proposed by the writer and fellow students (Brassard et al ,1980). This work proposes an extension thereof, following the general pattern of Mitchell's KWIK Systems Planning Method and ATED Strategy, and constitutes a possible course of action for the operationalization of them.

- MODEL'S CONCEPTUAL FRAMEWORK: KWIKSP METHOD AND ATED STRATEGY

Clearly derived from a systems approach to the transformation of an educational system, Mitchell's method and strategy are intended to help in the development of a self-instructional scheme. Briefly, the six steps of the KWIK (Knowledge, Wilyness, Ingenuity, and Keynote systemic perspective) method are (Mitchell, 1980, p.9:8):

A) clarify the reasons for the existence of the system and do so from different perspectives;

B) clarify the systemic objectives: what exactly is the nature and scope of the problem you are trying to solve or the system you are to produce;

C) examine and account for constraints under which you or the system must operate but beware of imagined constraints;

D) evaluate the resources available to you;

E) create an idea for, or a model of, a feasible sytem or process which is suitable for achieving all or many of your objectives, given your resource constraints;

F) if resources permit, try to identify several models or courses of action and select the best in the commonly recommended manner. However, Mitchell states, "don't fret if you produce only one all-encompassing idea for an educational system -- provided that the dominant systemic ideas are clear, that imagination has been used creatively, that your knowledge base is broad as well as deep, and that the resulting system can be described alluringly to clients and users."

Concerning the modification of an existing instructional system into a distant study system, and within the context of KWIK method's fifth step, Mitchell has proposed a simple strategy to achieve this transformation. The ATEDS (Autogenic Tele-Education Development Strategy) aims at providing a system for tele-education that "exploits the existing classroom-based operation and relies on inexpensive approaches to extend the institution's services" (Mitchell, 1980, p.9:13). Briefly, he proposes to start with the existing set of procedures, lessons and materials with the intention of gradually transforming most lessons into self-instructional modules. A topic analysis would assist in deciding which are the essential, desirable, and optional topics with which a student should be familiar. Next, a curriculum map can be prepared after which instructional modules are developed to operationalize that curriculum. Special emphasis is made on recognizing the need for human contact by identifying modules that require group activities. Finally, an ongoing evaluation should accompany the implementation of the system and its component subsystems.

In many situations one can discern on the curriculum map (or curriculum reticulated network) a set of nodes belonging to each of the "conventional" courses, so that a clustering of nodes into courses can be made with little or no conflict (eg., overlapping) between them. This may well be the situation in a department of education within a university, where different courses already tend not to cover the same topics and where prerequisites for a specific course are normally offered in other courses. Thus, notwithstanding the conceptual and practical advantages and the educational importance of working out a topic analysis and a subsequent curriculum map, an instructional modularization program may be started with the already existing courses. The instructional module's development can then be based on approaches like that of Dick and Carey (1978) or the Student-Centered Self-Instruction Module (Mitchell, 1980). In either case, among the many outcomes of the instructional analysis the following are of special relevance:

- each course is broken down into a series of instructional units or modules (viz., the nodes in Mitchell's curriculum map), which form a logically structured sequence of self-contained material;

- the (instructional) outcome of each module is clearly specified;

- entry behaviours and characteristics are specified for each module;

- an instructional strategy is chosen and followed throughout the design of the instructional unit;

- instructional materials are developed taking into account the specified input (entry skills) and output (desired outcome) while following the chosen strategy.

- INSTRUCTIONAL MEDIA SELECTION FOR TELE-EDUCATION MODULES

In a sense, planning an instructional module follows the general pattern of a needs assessment (cf Kaufman, 1972, 1976): the learner is taken as a "cognitive system", whose actual state (input) is assessed, the desired state (output) is specified, and a set of processes is chosen for the particular situation appropriate to the transformation of input into output (instruction).

One important point in this approach is that the process of instruction depends not only on input and output but on the particular situation of the system/learner, a fact that would be reflected in the selection of instructional strategies and in the development of materials. Thus, distant study programs will rely more, but not necessarily in whole, upon instruction through media different than upon student-teacher (eg, lectures) or student-student (eg, seminars) contact. For instance, a mixture of media making emphasis on print was decided to be most adequate for the Mexican CEMPAE Model for Educational Open Systems (which is actually being applied in the Primaria Abierta para Adultos and the Preparatoria Abierta projects):

> Despues de analizar cuidadosamente los caracteres psico-sociales, economicos y culturales del medio en que comenzaria a operar el modelo, se decidio que el material escrito seria el recurso mas importante para el aprendizaje, que la asesoria recibiria una atencion especial y que los medios audiovisuales (TV, radio, etc) realizarian funciones de apoyo a los contenidos de los libros (Contreras et al, 1977, p.11).

However, one must not forget that personal contact, as an example of interactive media, is an essential ingredient of any educational system: "the introduction of a systematic approach...is intended to facilitate learning, to increase efficiency, and above all, to supplement and aid instructors, not to replace them....[because] the instructor constitutes the break in an otherwise closed system, and controls the larger process of directing the learner's progress" (Schmid and Gerlach, 1977, pp.2-3).

The problem of deciding what mixture of one-way, interactive, and self-instructional media to use in a tele-education system is by no means a simple one. From a philosophical point of view it appears that a mixture of them, rather than deciding for one single strategy, is the only acceptable possibility:

> L'auto-education refuse la contradiction dialectique en mettant l'emphase sur le sujet. Or, le sujet n'existe que par l'univers, que par les autres. Cette conception de l'auto-education apparait donc comme etant incomplete, voire: reductionniste. La pedagogie rogerienne et la pedagogie inspiree de Summerhill mettent l'accent sur le "je" et oublient l'univers, dimension toute aussi importante.
>
> D'autre part, la pedagogie systematique et la pedagogie institutionnelle negligent la con c'-nce individuelle en mettant l'accent soit sur le professeur, soit sur le contenu, soit sur l'institution scolaire, soit sur la classe ouvriere. L'hetero-education est une forme de reduction de l'education et ne peut etre envisagee comme une philosophie qui rend compte de tous les phenomenes de l'education.

> Il nous faut donc depasser cette antinomie apparemment irreductible. Le depassement ne sera possible que s'il y a mediation de l'auto-education par l'hetero-education et vice-versa. Ainsi, l'un devient le contenu de l'autre et cela modifie completement les perspectives. L'individu se centrera sur le developpement de la collectivite, des autres, et de l'univers; il entrainera naturellement l'auto-developpement de l'individu. La collectivite se centrera sur le developpement de l'individu et profitera ainsi de cette evolution de la conscience. La centration sur soi, qu'on essae d'eviter par cette conception de l'education, entraine inevitablement une regression (Bertrand, 1978, p.153).

As well, from a practical point of view it appears that the mixture should be changed constantly to maintain a "permanent Hawthorne effect". But a recipe to obtain the right mixture of independence and interaction for the ideally cost-effective and educationally efficient remote-learning system is impossible, "simply because a system can only be conceived in relation to the country and context in which it is set" (Daniel and Marquis, 1979, p.41).

As a result of instructional analysis a number of modules can be planned for each course, where the number of student work hours for each module is specified (adding up to the number of student work hours per course plus lecture hours originally allocated), and the number of hours needed for instruction through different media is made explicit. The proposed model is designed such that any number of instructional modules can be specified.

The selection of an instructional strategy and/or instructional media for a particular situation are still questions with no definite answer. Generally speaking, given the input to an instructional process and a desired output there is no single set of rules to decide which instructional strategy would best assist in the transformation of input into output; there is not even sufficient information about the efficiency and effectiveness of any single strategy.

Similar conclusions can be drawn from a review of the relevant literature on media selection. A first consideration is the problem of different learning or cognitive styles. Research has been done leading to the acceptance of a variety of styles of learning as an integral input to any instructional process. However, little agreement exists as to what these cognitive styles are (cf., Pask, 1976; Entwhistle, 1979; Jonassen, 1979), and even if it is possible to distinguish a person's cognitive style in any given category, the question still remains as to whether a person's cognitive style is immutable (Nunney and Hill, 1972).

Not only is there a lack of consensus as to what the different learning styles are and how to assess the style of a particular learner, but intertwined with this is the problem of developing different instructional strategies directed to satisfy different cognitive styles. One example concerning the production of instructional materials is found in instructional media selection, where "so little research has considered the role of cognitive styles as predictive variables. The ability to predict the effectiveness of various media, modes, and/or symbolic codes with respect to specific learner types should prescribe the future of media research" (Jonassen, 1979, p.28).

Instructional media selection based on students' characteristics was anticipated by Gerlach (1966) when he proposed a response-oriented approach rather than a stimulus-oriented one; the response-oriented approach clearly involves studying the effectiveness of different instructional media for different cognitive styles.

This approach is in agreement with Nunney and Hill (1972) in that "by using cognitive style mapping we could determine which students can and do learn better from TV, for example," and by implication, that "different elements of

Educational Technology can be used to insure success for certain students; [but] none is superior for all students." As Sleeman et al (1979, p.v) pointed out:

> each learner has individual needs and is different from other learners. Under serendipitous conditions, some learning experiences may be effective for all learners. Success is achieved when the design of the learning experience is specific to whatever the learner requires.

This is indeed a tremendous task to be undertaken. It requires much research, and the results would very likely imply costly production programs. This is why educational technologists have traditionally adopted a more political attitude designing "feasible" media programs, like the Open University one where questions such as "how many half-hours of television to request for a course just being designed" (Schramm, 1977, p.20) characterize the level of discussion. This attitude is based on beliefs like "students learn from any media, in school or out, whether they intend or not, whether it is intended or not that they should learn" (Schramm, 1977, p.267). As stated above, these statements are being questioned in the light of recent research results. Thus, although it may be acceptable to say that until more information is available, problems may be coped with by designing politically and administratively feasible programs as best we can educationally, it is not possible to praise and justify these pragmatic solutions that ultimately subordinate educational aims to other factors. Rather, the need for more educational research evidence must be recognized as the only way to develop sound media programs in the long run.

Criteria other than intrinsic learner characteristics have also been considered for media selection. Kemp (1971; 1975, p.49) has presented an algorithm intended to help in this selection, primarily based on the instructional designer's assessment as to the most efficient means to convey the information to the learner. Three different situations (independent study for independent learners, small group interaction, and presentation to regular size class or large size group) are considered. In any one of them the designer has to decide what kind of, and in what form, experience is required for the instructional communication; the algorithm leads the designer to the selection of one group of instructional media.

Allen (1967) provides a method for selecting media based on the instructional designer's assessment of the type of learning involved. He considers nine different types of media and six types of learning and classifies the different matches between them into low, partial, or high proficiency.

This method was extended by Lonigro and Eschenbrenner (1973) who included production costs of instructional media (measured as high, medium, or low cost) to produce a "game board" for media selection.

As a guide for future research, Johnson and Johnson (1970) and Goodman (1971) have stressed cost-effectiveness as a main determinant for media selection. In their work cost-effectiveness refers to a statistical assessment (eg., which of the available and cheap A/V materials would better satisfy the average student), and no practical applications are offered. However, the value of media cost-effectiveness as a definitive criteria for selection has been challenged because "there is no one best medium and as several systems may be equally effective, the final selection between systems should be based on external considerations such as cost, availability of media, and user preference" (Rodwell, 1978, p.57). It is interesting to note that some researchers have found that strong user preferences for media do not appear to influence short-term learning outcomes (Becker, 1963; Miller, 1969), although the learner's attitude to method of instruction may in fact influence learning outcomes over larger periods of time (Palmer, 1975).

Needs assessment has been proposed by Hug (1975) as a planning tool that can help develop a media program. His main interest is to develop an educational media program completely integrated within a school curriculum, which in turn would be "based on social processes and life functions, [that] would reflect the values and needs of the existing social order. [Thus] the task of the schools would be to prepare students with the attitudes and skills necessary to participate in society." Although this conception provides an interesting rationale for curriculum design and instructional media development, it assumes that instructional media selection is not based on particular considerations such as a module's instructional design and the characteristics of the learners for which the material is intended.

Much more relevant for planning instructional modules in a tele-education development program is the approach found in Kozma et al (1978, pp.52-65). As was said before, they classified instructional media into one-way, interactive, and self-instructional types. In agreement with Tosti and Ball (1969) media also vary in the way they perform three functions critical to learning: present a stimulus, require a response, and manage the immediate instructional environment. The way each medium performs these functions, they state, will determine the instructional task for which it is appropriate. Accordingly, Kozma et al (1978) offer tables presenting the features of each one of seventeen selected media, representative of the three types (one-way, interactive, and self-instructional) available, under each of the three tasks (stimulus encode, response, and management).

The final selection of an instructional mode, they claim, should be based on the stimulus, response, and management demands of the task and the students, and can be assisted by the use of their tables.

Let us assume that within the instructional modules development program a selection of one medium per module is made following the criteria in Kozma et al (1978). The subsequent task of actually developing a module is then left to the instructional designer; whether s/he is a teacher, an intern, or an expert, it is by no means an easy one. As Erdos (1975) has pointed out, "in the distance teaching situation the tutor preparing the presentation of teaching material [often] lacks the stimulus of the presence and immediate reaction of his students. He has to try to place himself in the position of the distant learner, and imagine what his reaction will be. He has to avoid monotony in presentation, and devise techniques of preventing the student from sinking into a passive state in which he assimilates little of what he is trying to learn." In a word, the tele-education instructional designers have to be engineers more than being artists or scientists: rather than looking for the most beautiful or the best kind of instruction, the challenge is to be as creative and wise as possible but being effective now and with the (limited) available knowledge and resources.

- TO ADAPT OR TO PRODUCE MATERIALS?

Once the instructional analysis of a module is performed and the characteristics of the instructional materials needed are established, one may well ask if some of the materials available in the (international) market could be adapted to the particular situation under study. In my opinion this will seldom be the case. In the first place, the outcome of instructional analysis depends strongly on features that are peculiar to the situation under study: education, cultural, and social characteristics of the target population, entry behaviors required, precise instructional outcomes sought, as well as individual instructional designer's "style", may result in specific requirements that could only be met by instructional materials developed to those ends.

Secondly, administrative procedures may hinder the use of available funds to purchase and adapt materials. Administrators are usually reluctant to allow some flexibility in the application of a budget whereby certain part of the funds allocated, eg., to human resources could be used to other ends (like purchasing materials).

However, assuming that one could find materials which seemed adequate from an instructional point of view for a given module, and assuming possible and desirable to purchase them, it still has to be decided whether the alternative of buying, revising, and adpting material is more cost-effective than producing it. Stolovitch (1978) has developed a four-step decision model to this end:

1) Estimate investments to produce a Revised and a New material in terms of Cost, Time, and Human Resources needed. Let us assume, following the example offered by him, that the estimates lead to the following figures:

	Revised Material	New Material
Cost($)	2600	3500
Time(hrs)	100	75
HR(#)	20	30

2) Reduce figures for revised material to an absolute scale, dividing each line (ie, Cost, Time, and HR) by the corresponding figures under the New Material column:

Revised Material

Cost	2600/3500 = 0.74
Time	100/75 = 1.33
HR	20/30 = 0.67

3) Assign weights to each factor, such that they add up to 10. Weights represent the relative importance of each factor, and this assignment necessarily involves a subjective element. Let us assume that weights are "guesstimated" as 5,2,3 for Cost, Time, and HR, respectively.

4) Calculate the Relative Investment of revised material multiplying each of the absolute-scale figures for each factor by its weight and adding up the three products. If RI < 10, then purchase, revise and adapt the material; otherwise, reject it and search for another material or design a new one. In our example,

RI = (0.74) x 5 + (1.33) x 2 +

+(0.67) x 3 = 8.37,

which is less than 10, and thus this hypothetical material could be accepted. Of course, the closer the RI moves toward 10, the less cost-effective the purchase, revision, and adaptation is.

In this thesis the assumption was made that all materials would be produced. Apart from the reasons given above, the undertaking of a production program has an utmost value for the particular situation studied in the next Chapter, as it constitutes an essential learning experience for the people involved. If, however, in a practical application it is found to be more cost-effective to adapt some materials than to produce them, the following two considerations have to be made: first, substract from the budget originally available the total needed to purchase, revise and adapt those materials (and consequently, develop a plan to implement this revision allocating the necessary resources for it); and second, for each course where revised materials will be allocated, substract from the number of required hours of instruction through each media the amount corresponding to revised materials. In other words, establish what is the budget available for the production program, and determine the actual needs are for material to be produced for each course.

- DETERMINING PRODUCTION COSTS FOR MEDIA-BASED INSTRUCTIONAL MATERIALS REQUIRED

Once the number of required hours of instruction per course through each one of a set of different media is known, the next question the educational systems developer has to answer refers to the feasibility of the implementation of that modularization program. Specifically, if one knows that in general instructional media production costs are high, and that in most situations proposed budgets for such programs cannot be afforded, then what are the courses of action available to the planner?

The approach taken in this work involves the optimization of the modularization-budget constraints using a computer simulation. Let us assume that the number of hours of different instructional media required per course is conceptualized as an element of a matrix, where different rows refer to different courses and columns to media; see Figure 1 .

FIGURE 1

DEFINITION OF A MEDIA-MIX MATRIX

MEDIUM # / COURSE #	1	2	3	. . .	m
1	X_{11}	X_{12}	X_{13}	. . . .	X_{1m}
2	X_{21}	X_{22}	X_{23}	. . .	X_{2m}
3	X_{31}	X_{32}	X_{33}	. . .	X_{3m}
4	X_{41}	X_{42}	X_{43}	. . .	X_{4m}
.					
.					
.					
n	X_{n1}	X_{n2}	X_{n3}	. . .	X_{nm}

NOTE: In this figure a media-mix matrix is shown where n different courses and m different media are considered. For example, the element X_{23} refers to the number of hours of instruction required in course #2 through medium #3 (say, Television)

According to this, the sum of the elements within a given column would equal the number of total hours of instruction through that specific medium required by the program. And the sum within a row would equal the number of total hours of different media required by a particular course; see Figure 2.

FIGURE 2

ROW AND COLUMN TOTALS IN A MEDIA-MIX MATRIX

MEDIUM #	1	2	3	. . .	m	COURSE HRS. TOTS.
COURSE #						
1	X_{11}	X_{12}	X_{13}	. . .	X_{1m}	H_1
2	X_{21}	X_{22}	X_{23}	. . .	X_{2m}	H_2
3	X_{31}	X_{32}	X_{33}	. . .	X_{3m}	H_3
4	X_{41}	X_{42}	X_{43}	. . .	X_{4m}	H_4
.						.
.						
.						
n	X_{n1}	X_{n2}	X_{n3}	. . .	X_{nm}	H_n
MEDIA TOTALS	M_1	M_2	M_3	. . .	M_m	

NOTE: Row and column totals were added to the media-mix matrix of figure 1. For example, H_2 represents the number of hrs. of instruction required by course #2 through all the media considered, and is obtained by computing the sum $H_2 = X_{21} + X_{22} + \ldots + X_{2m}$ Similarly, M_3 is the total number of hours of instruction through medium #3 in all courses, and is obtained by computing the sum $M_3 = X_{13} + X_{23} + X_{33} + X_{43} + \ldots + X_{n3}$

From now on, production costs will refer to man-hours needed to produce one hour of instruction through a particular medium, and will include some fixed costs for materials used and facilities rented for the production of that unit hour, as well as pre-production costs such as research into the subject, analysis of topics, etc.

If one multiplies each column sum by the cost of production of each hour of instruction through that particular medium, then the sum of all such products would give the total cost of media production for the program; see Figure 3.

FIGURE 3

TOTAL COST OF MEDIA PRODUCTION

Media Totals	M_1	M_2	M_3	. . .	M_m
Media Costs	C_1	C_2	C_3	. . .	C_m
TOTAL COST PER MEDIUM	M_1*C_1	M_2*C_2	M_3*C_3	. . .	M_m*C_m

NOTE: To the media totals in Figure 2 the unitary production costs per medium were added here. Total cost of the production program per medium is calculated multiplying medium total times the corresponding unitary cost. For example, the total cost of production for medium #3 would be M3*C3.

The total cost of the production program would be calculated as the sum of total costs per medium, ie,

TOTAL COST = M1*C1 + M2*C2 + M3*C3 + ... + Mm*Cm

Two difficulties arise at this point. First, the latter statement is not rigorously true although it constitutes a fairly acceptable approximation. It is generally found that instructional media producers tend to spend more man-hours producing the first units or modules of a program than in the production of subsequent ones. Thus, it is not exactly true that the cost of producing, say, 30 hours of instruction through film equals 30 times the cost of prodicing one hour of film. In fact the problem rests upon how to calculate the unit cost of production: the average unitary cost would be different if we talk of producing a few hours than if we are considering a massive production. However, we may reasonably assume that if the production program is given to a group of "temporary producers", none of whom will stay in the program long enough to produce large amounts of instructional hours through one particular medium, then the average unitary production costs can be fairly well approximated and considered constant for the whole program. The same can be said if the production program is given to experienced producers, the difference being that the average unitary production cost would most probably be lower in the latter situation than in the former.

The second and more difficult problem refers to determining the actual values of those unit costs of production. Most literature in media costs deals with reproduction, rather than production, costs (cf., Kemp, 1975;

Hancock, 1977; Jamison, 1977; Jamison et al,1978; Schramm, 1977). Little relevant literature is available, and most of it is rather imprecise or non-quantitative. For example, a common practice is to classify media production costs as high, medium, and low (cf., Lonigro and Eschenbrenner, 1973). On the other hand, the few quantitative references available tend to give rather vague indications; for example, Chambers and Sprecher (1980) report courseware developing cost for CAL ranging from 50 to 500 hours of preparation to produce one hour of student CAL contact time at a terminal, with 100 hours "appearing to be the most widely accepted rule of thumb" (p.337).

The latter is an indication of the difficulty found in quantifying production costs: beyond ranking them on an ordinal scale little can be done with respect to generalizable quantitative assessments because production costs vary from one producer to another. In other words, the quantification of production hours depends on intrinsic characteristics of the producer or production group. These characteristics, however, cannot easily be measured experimentally because that would increase considerably the costs of the whole program. Rather, an assessment can be obtained from people experienced in working with similar production groups, and utilizing that assessment as an objective to be accomplished: if an hour of printed material was planned to cost an average of 40 man-hours to produce, then the production program should be managed so as to keep within this norm. This approach will be followed in this thesis.

- OPTIMIZATION OF THE MODULARIZATION-BUDGET CONSTRAINTS

There are several procedural possibilities suggested by the model proposed in this thesis. If the total cost of media production is affordable within the budgetary constraints, media hours can be allocated to each course as the instructional development program had planned. However, if the total cost of production surpasses budgetary constraints (which is most probable), then a modification of the goals set up by the modularization program will be needed in order to reduce costs; but a trade-off is required between goals and resources.

A first approach to this modification is to minimize the total costs while preserving the total number of media hours per course. This approach seems most applicable when there is no specific budgetary upper limit; for example, when media production will be undertaken by interns in an Ed. Tech. program, where monetary compensation for labour is not required but one is still interested in minimizing the total man-hours needed for production.

It may well happen that after minimizing the cost the program still surpasses the budgetary constraints; it may also be that the budgetary constraints were established and known from the beginning. In those situations it seems better to adopt another approach, maximizing the total number of hours of instruction through media that one could afford within the given budget.

In each of the two alternatives mentioned above, some considerations have to be made concerning global media-mix as well as minimum and maximum hours permissible per media. These would be reflected in the set of constraints for each optimization problem.

From the outline of the possible situations above, it is clear that a linear objective function and a set of linear constraints can be identified, making each amenable to formulation as an LP problem.

Generally speaking, linear programming (LP) is:

> a mathematical tool for allocating scarce resources to competing demands for them. It helps one to find the best value for the total outcome of one's decision while simultaneously satisfying several requirements imposed by the situation (Mitchell, 1974, p.14).

As any other Operations Research (OR) technique, LP emphasizes systems analysis of ongoing operations at a molar level while focusing on the function and structure of a system to obtain information to guide policy and operational decisions. The description of a process or complex of interrelated entities typically requires the construction of some kind of representation or model of it; predicting and comparing outcomes of alternative strategies or explanations which might occur in the real system can be accomplished by conducting experiments (viz., simulations) on the model (Mitchell, 1974, p.6).

In the specific case of LP, a process within a system is described by means of a set of variables (activities), which represent quantifiable elements or subprocesses that are (presumably) essential for the desired description. Next, it is assumed that the process of interest can be described as a linear combination of the activities, which means that the process will be represented as a function of the set of activities where each one of them is multiplied times a coefficient (representing a "unit cost" for that activity) and all such products are added up. This function is called the Objective Function. The aim in any LP problem is to optimize, ie., either maximize or minimize, the objective function when the process is restricted by a set of conditions (constraints), each of which is represented by a linear combination of all or some of the activities. The "solution" to an LP problem, thus, is a set of values for the activities that optimizes the objective function under the given set of constraints.

The relevance of OR techniques for educational research has been discussed by Mitchell (1974); as well, many examples of their application in education exist (1).

- REASSIGNMENT OF THE MEDIA-MIX MATRIX AS REQUIRED BY THE OPTIMIZATION OUTPUT

After a solution is found a set of either new column-totals or row-totals is obtained. These new totals require a change to be made in each of the elements of the matrix.

With the first approach mentioned above, when attempting to modify the original matrix to conform to the optimal totals, one finds that transformation of the individual segments would result in a transformation of the hours per course, numbers which should be respected since they were derived from the educational criteria mentioned above. This situation happens typically when the optimal financial solution is crudely superimposed onto the original media mix matrix by multiplying each element in a column times the quotient of the new (optimal) figure for the total hours through that particular medium divided by the old total. Thus, all such modified entries within a column in the matrix would add up to the new column-totals, which means that the modified matrix conforms to the optimized (minimum cost) decision. However, row totals would not add up to the preassigned figures after the modification is made, which means that the educational decision as to the number of media hours per course is no longer being respected. An algorithm for reassigning the entries in a media mix matrix that respects both column and row totals was developed by the author and fellow students. The procedure we developed represents a breakthrough in the field of educational planning as it reassigns a media mix matrix while respecting both budgetary and educational constraints. For a detailed explanation of this method, see Vazquez-Abad et al (1980); a version of it (from Brassard et al, 1980, Appendix 2) is offered in Appendix A. In this thesis a FORTRAN program that implements this algorithm was run at Concordia University's Cyber 174 to reassign media mix matrices.

With the second approach a maximum number of hours of instruction through each media is obtained given a fixed cost. Thus, the typical situation would be one where the total number of modularized hours will be less than the target figure. Two alternatives for reassignment arise: distributing the total of hours per media obtained from the optimization problem among all courses by simply multiplying the quotient new total/old total per media times each element within the column; or to negotiate the allocation of those new totals to only some of the courses, such that those determined on educational criteria to be the most deserving could become completely modularized.

– ESTABLISHING POLICIES AND SCHEDULES FOR IMPLEMENTATION

In either situation, the reassigned matrix constitutes an optimized set of objectives with which to plan the implementation of the modularization program. In each of the alternatives developed guidelines for implementation plans can be established that include general policies and considerations about its schedulling. Detailed implementation and management of a tele-education system, however, are beyond the scope of this thesis; relevant literature can be found that cover this topic (see Chapter 6).

– DETERMINING THE REQUIREMENTS OF AN LRC

Within the guidelines for implementation considered it may be necessary to plan the requirements that a Learning

Resources Center (LRC) should meet. In order to do this the LRC can be modelled as a Queuing or "waiting line" system which will operate on the end-state situation (cf, Mitchell, 1980, Chap.8).

Queuing theory is another OR technique whose relevance for educational research has also been discussed by Mitchell (1974). Applying QT to the design of an LRC means that the latter is seen as a system composed by several channels (eg, one channel per instructional medium considered) and several servers per channel (eg, several carrels available per instructional medium). Student arrivals at the LRC is considered as a random variable (usually following a uni- or multi-modal Poisson distribution) that would set up "waiting lines" for different channels depending mainly on arrival rate, number of carrels available per channel, and channel's serving rate (eg, the average number of lessons or modules that can be shown per channel in an hour). The system can be modelled mathematically yielding equations that relate arrival rates, serving rates, and number of carrels with average waiting time and/or length of the waiting line. If one establishes a maximum average waiting time per channel that would be tolerable, the equations can be solved for the number of carrels needed per channel in order to meet the requirements of arrival and serving rates within the limits for average waiting time. This will be explicitly done in the next Chapter.

- SUMMARY OF THE MODEL

The model offered in this Chapter can be summarized in the following 12 steps:

1) Clarify the reasons for the existence of the system and the systemic objectives.

2) Prepare a curriculum map or reticulated network. Call each node a "module" and a set composed of (some fixed number of) related nodes a "course".

3) Perform an instructional analysis on each module, clarifying its entry behaviors and characteristics, instructional outcomes, and instructional strategy to be followed.

4) Determine what instructional materials need to be developed for each module. In particular, determine the number of hours of instruction required through each one of a set of different media following educational considerations.

5) Express that information in a "preferred" media-mix matrix. Determine the total number of hours of instruction desired per course

through all media, and the total cost of media-based material desired per medium, by finding (respectively) each row- and column-total in the matrix.

6) Determine (perhaps just estimate) unitary costs of producing media-based instructional material for each one of the different media under consideration, for the production group involved.

7) Determine the cost of producing the media-based material desired:

a) if cost is affordable go to step 11;

b) if it is not affordable, an optimization of the modularization-budget constraints is needed: go to the next step.

8) Produce some planning alternatives by optimizing the modularization-budget constraints under different conditions. For example:

a) Express the total production cost as a function of the total number of media-based material per medium and minimize this function; constraints should include the preservation of the total number of media hours per course and global media-mix considerations (which in turn may or may not include a minimum number of hours for some of the media under consideration).

B) Express the total number of hours of instruction through media as a function of the number of media hours per course and maximize this function; constraints should include the preservation of production costs within affordable limits and the global media-mix considerations mentioned before.

9) Each of these alternatives will produce a set of either new column-totals (eg, in 8a) or row-totals (eg, in 8b) in the media-mix matrix. Use the Reassignment Algorithm to find the changes to be made in each element of the matrix that the new totals require.

10) Establish implementation plans (ie, implementation policies and schedules) for each of the alternatives developed.

11) Determine (if applicable) the requirements that the LRC should meet at "end-state" situation in order to implement each alternative plan.

12) You should now have enough information in order to decide which alternative to choose. You can start by rejecting those which are not technically feasible; it is probable that you have already started doing this after step 8 was completed (besides from the fact that optimization indeed implies the rejection of an infinite number of unfeasible situations). But when deciding among technically feasible solutions, refer yourself to step 1 trying to get involved in this decision process all the professors affected by the innovation that will be inforced.

CHAPTER 5: SIMULATIONS

A set of computer based experiments was run to compare the outputs of the model under different input situations. The point of the simulations was on the one hand, to show how the whole procedure would be used in a real situation, and on the other hand, to study the effects on the plan of changing some input information.

- FRAMEWORK AND NEED FOR A TELE-EDUCATION SYSTEM

An educational system was considered such as the one described in chapter 3. In order to create a "real" situation let us assume that the Department of Education at Concordia University wants to transform the Graduate Programme in Educational Technology into a tele-education system.

The Programme is composed of 35 different 3-credit courses, four of which (courses 1 to 4) are compulsory for every student. Students must also choose between two courses (either course 5 or 6) as a fifth compulsory course. Students must take another 8 elective courses (chosen from among courses 7 to 35), work on a 15-credit Supervised Internship (thus equivalent to 675 hours of student work time), and produce a thesis or thesis-equivalent.

There are six full-time professors assigned to the Educational Technology Programme. Each faculty member is responsible for teaching 12 credits per year and supervising internships and theses. The number of faculty is fixed and is, therefore, a constraint that must be respected. Assuming a workload per professor of 110 hours per thesis/thesis-equivalent supervised and 46 hours per internship supervised (based on Mitchell, 1977), an average workload per professor per term is as follows. If we assume that a term comprises 15 weeks, a total of 600 hours constitutes the total load of a professor per term on the basis of a 40-hour week. If we further assume that there are 26 lecture hours per course in a term, and that each lecture hour demands from the lecturer another 3 hours for research, extra contact with students, and evaluation, then a total of 208 hours of each professor's term-workload will be allocated to courses. Should the other 392 hours be divided so as to allow a maximum number of students in the system, a total of five students can be supervised per professor per year. With the figures quoted above, this means that 5 x 110 = 550 hours per year or 275 hours per term, and 5 x 46 = 230 hours per year or 115 hours per term are devoted by each professor to thesis/thesis-equivalent and internship supervision, respectively. Such a situation would result in a professor's average workload per term being as in Table 1.

TABLE 1

AVERAGE WORKLOAD PER PROFESSOR PER TERM.

Internship Supervision	Thesis/thesis-eq. Supervision	Courses	R&D and Administration	Total
115	275	208	2	600

Assumptions: 110 hours/thesis (*)

46 hours/internship (*)

3 hours preparation/hour in class

(*) Based on Mitchell, 1977

Referring to the figures in Table 1, one can deduce that with an enrollment of 30 students per year, the average workload per professor (thesis/thesis-equivalent and internship supervision plus courses) would leave two hours per term for research and administration. This is obviously not the situation. What actually happens is that professors find that they must work more than 40 hours peer week to fulfill their commitments. Because course and thesis supervision requirements are unavoidable, they are therefore met in full. Despite the extended work week, however, there is insufficient time to fulfill all obligations. As internship supervision seems to be the weakest link in the chain, it is often the activity most likely to be neglected.

The strategy proposed here, first suggested by Brassard et al (1980), is intended to provide such a system with materials for a tele-education studies program. A useful by-product, however, is its function as a paradigm for the management and enrichment of the internship. In a plan such as the one outlined, students would work on projects with immediate application, could follow through on the evaluation and revision of their materials, and, in addition, participate in the overall design and planning of an instructional system whose aims and goals as well as objectives are understood.

Let us assume that the transformation of this educational system into a system of tele-education starts with the modularization of some courses. Let us further assume that following a study of the curriculum and the past flow of students through it, it is concluded that the six compulsory courses and the six elective courses with highest enrolment should be the first ones transformed into tele-education courses; for the sake of the argument let us name these courses number 1 to 12.

- SETTING UP THE MEDIA-MIX MATRIX

The next step is to ask the professors to perform an instructional analysis of each of those courses with the aim of redesigning them as self-instructional courses. As a result, a number of modules per course will be planned and a preferred instructional strategy for each module will be determined. As part of that strategy, instructional materials requiring different media will be needed. Let us assume that all such instructional materials can be classified, according to the media required, into one of the following categories: Lecture, Discussion, TV, Audio, Slide/Tape, Print, Simulation/Game, or CAL materials. One advantage of using only these media is that the cost of raw materials need not be considered because the University has the necessary production facilities and budget.

Given that we are concerned with the modularization of a Graduate Programme, we can assume that it is not necessary, nor is it desirable, to provide the student with instructional activities for each course spanning the total of the 135 hours equivalent to the 3 credits awarded. Rather, we can plan for the modularization of 45 hours per course, on the basis that graduate students will spend at least two extra hours per hour of course in independent activities related to each course's contents, eg, reading and writing.

As a result from the instructional analysis and planning process a preferred media mix matrix is established yielding the figures in Table 2.

TABLE 2

PREFERRED MEDIA-MIX MATRIX.

MEDIA / COURSE	L	D	TV	A	ST	P	C	SG	Tot.
1	2	18	-	7	-	12	-	6	25
2	2	6	5	-	6	18	8	-	37
3	2	4	7	8	5	13	3	3	39
4	-	10	7	7	-	13	-	8	35
5	-	-	-	-	-	25	15	5	45
6	-	-	7	10	-	16	8	4	45
7	-	-	7	-	-	13	20	5	45
8	-	5	7	10	8	15	-	-	40
9	-	-	12	7	15	11	-	-	45
10	2	13	-	8	8	14	-	-	30
11	2	8	-	-	5	15	15	-	35
12	2	10	4	-	4	8	-	17	33
TOTALS	12	74	56	57	51	173	69	48	

NOTE: L: lecture; D: discusion; TV: video-cassette; A: audio-tape; P: printed material; C: computer-assissted-learning; SG: simulation/game; Tot.; total hrs. per course (excluding L and D)

- INSTRUCTIONAL MATERIAL PRODUCTION COST

The strategy suggested for the production of the instructional materials is to assign students to work in groups, supervised by professors, on the development of such materials in fulfillment of the internship requirement. The first advantage of this strategy is the resulting change in the professors' workload. Given that the students work in groups, professors would not spend as much time supervising a group's work as they would have supervising five independent students, and this supervision, being concerned with a structured group project, can be done much more efficiently. A second advantage is that at the end of the modularization program the number of teaching hours per course will be reduced considerably. The hours gained from internship supervision and courses may then be allocated to R&D and schedulled tutorials.

The attention that thesis/thesis equivalent demands from professors, as explained before, translates into a large number of hours, creating a ceiling on the number of students that can be admitted. Thus, with six full-time professors in the Programme, a maximum of 30 students constitutes the upper limit to this system's yearly input. Using the figure of 675 hours of student work time as equivalent to an Internship, a maximum of 30 x 675 = 20,250 man-hours is available per year for the materials production program. Let us assume that the search and production of material for Lectures and Discussions is the responsibility of each professor. Using the figures for production costs of the other six media in Table 3, it is clear that the preferred media matrix implies a long-range production program as no less than four years would be required to complete it.

TABLE 3

MEDIA PRODUCTION HOURS (COSTS) FOR PREFERRED MATRIX.

	TV	A	ST	P	CAL	SG	TOTALS
Hours of Lessons	56	57	51	173	69	48	454
Production Hours (*)	300	55	100	40	400	400	
TOTALS	16,800	3,135	5,100	6,920	27,600	19,200	78,755

(*) Based on Brassard et al,1980 (Figures obtained from direct communication with production experts.)

All figures refer to the approximate number of hours required for research, production, and evaluation of materials.

Note: TV: Video-Cassette; A:Audio-Tape; P: Printed material; CAL: Computer Assisted Learning; SG: Educational Simulation/Game

- OPTIMIZATION: MINIMIZATION OF PRODUCTION COSTS

I) ALL MEDIA

The importance of the optimization model proposed in the previous chapter becomes evident at this point. We consider an LP problem with six activities:

TV: # of hrs. of inst. via VCR w/ unit cost of 300 hrs.

A:	Audio-Tape	55
ST:	Slide/Tape	100
P:	Printed Material	40
CAL:	Comp.Ass.Learning	400
SG:	Simulation/Game	400

Thus, the objective function can be identified as a linear combination of these activities where the coefficients are the unit costs quoted above. The goal is to minimize the objective function; ie., to minimize the total media production program cost.

It is clear that the constraints for this problem cannot be limited to cost alone, as this would result in all of the modules consisting of only printed material. That is, if one ran the LP problem with no other constraints than a required total number of media hours, the solution would be 454 hours of printed material with a cost of 18,160 man-hours.

Additional constraints concerning the global media-mix and maximum and minimum number of hours permissible per media have to be introduced.

Given that budgetary constraints must modify the educational decisions first taken, the problem becomes one of priorities. Unfortunately, educational considerations are usually ignored in this step. Operating on the assumption that educational goals should not be subordinate to financial considerations, the first constraint in the LP problem involves the amount of modularization desired: if, from an educational point of view, professors decided that 454 hours of instruction should be produced through the selected six media, this decision has to be respected. Thus, the total number of hours of instructional material through TV, Audio, S/T, Print, CAL, and SG must equal 454 hours.

The following additional constraints are introduced taking into consideration factors such as the portability of the materials, avoidance of a totally print-based or print&audio-based program, and professors' assessments as to the lower limit of hours of each of the different media that would be acceptable based on the needs of each course. Suppose that consultation with faculty yield the following:

1) The minimum number of hours of each medium is to be: 13 hours of TV, 19 of AudioTape, 20 of SlideTape, 12 of CAL, and 8 of Sim/Games. No minimum is imposed on printed materials.

2) Because tapes and printed materials are the cheapest to produce, no more than 60 hours of tapes and no more than 300 hours of print are allowable.

The above information is translated into the following equations:

minimize $z = 300\ TV + 55\ A + 100\ ST + 400\ CAL + 400\ SG$

Subject to:

$$TV \geq 13$$
$$A \geq 19$$
$$ST \geq 20$$
$$CAL \geq 12$$
$$SG \geq 8$$
$$TV + A + ST + P + CAL + SG = 454$$
$$A \leq 60$$
$$P \leq 300$$

These equations were used as input for the BASIC-SIMPLEX program available on the Cyber 174 at Concordia University. The results are reported in table 4.

TABLE 4

OPTIMAL VALUES OF MEDIA HOURS.

COMPLETE MODULARIZATION USING EIGHT MEDIA.

MEDIUM	HOURS
TV	13
A	60
ST	61
P	300
CAL	12
S/G	8

Z = 33,300

The solution again requires more man-hours than what is available. However, a plan can be developed to implement it as a two-year production program, at the end of which the set of 12 courses would attain the degree of modularization sought. For the implementation of this plan it is necessary to know what the distribution of media hours per course should be; to this end the reassignment algorithm explained in Appendix A is used yielding the resulting media mix matrix displayed in Table 5.

TABLE 5

REASSIGNED MEDIA-MIX MATRIX. COMPLETE MODULARIZATION USING EIGHT MEDIA.

MEDIA / COURSE	TV	A	ST	P	CAL	SG	Tot.
1	-	6.9	-	17.5	-	0.7	25.0
2	1.0	-	7.2	27.9	1.0	-	37.0
3	1.5	9.0	6.3	21.5	0.4	0.4	39.0
4	1.6	8.6	-	23.7	-	1.2	35.0
5	-	-	-	42.1	2.2	0.7	45.0
6	1.6	12.3	-	29.2	1.3	0.6	45.0
7	2.5	-	-	36.6	4.8	1.1	45.0
8	1.2	9.4	8.4	20.9	-	-	40.0
9	2.4	7.5	17.9	17.4	-	-	45.0
10	-	6.4	7.1	16.5	-	-	30.0
11	-	-	6.6	26.3	2.3	-	35.0
12	1.3	-	7.7	20.5	-	3.4	33.0

NOTE: TV: video-cassette; A: audio-tape; P: printed material; CAL: computer-assissted-learning; SG: simulation/game; Tot.: total hrs. per course.
Numbers are rounded-off to the first decimal place.

According to the data in Table 5, two alternatives for schedulling the production program are possible. In the first one may divide the production plan by either media or courses considered. For example, all Print, CAL, and SG materials could be produced during the first year at a cost of 300 x 40 + 12 x 400 + 8 x 400 = 20,000 man-hours, leaving all TV, A , and ST materials to the second year at a cost of 13 x 300 + 60 x 55 + 61 x 100 = 13,300 man-hours. This alternative has the advantage of demanding all interns and professors to concentrate only on problems related to three media per year. On the other hand, courses 1 to 7 can be modularized during the first year, at a cost of 19,457 man-hours, leaving courses 8 to 12 to the second year at a cost of 13,843 man-hours. This second alternative implies that professors should have interns working on all six media in the two years, but it presents the advantage of producing 7 complete tele-education courses by the end of the first year.

II) PRINT AND AUDIO ONLY

The second possible alternative is to produce a tele-education system based only on print and audio lessons. The original media mix matrix should then be modified by professors in order to produce one where only these two media are considered in addition to lectures and discussions. As a result, a production program may result which is feasible in terms of the available production man-hours. In fact, this is likely to be the situation: with a cost of 55 hours for audio and 40 hours for print, the total media cost would range between 18,160 hours (for print only) and 24,974 (for audio only). In the latter situation, after the first year 7 interns working for the first term of the second year or all 30 of them working for 4 extra weeks would be sufficient to complete the modularization.

Let us assume that a minimization of cost is sought anyway because it may liberate intern-hours to work on different projects (eg., starting the modularization of other courses, within or outside the Programme). The corresponding LP problem would be stated as:

Minimize $Z = 55\ A + 40\ P$

Subject to: $A + P = 454$

plus any other constraint(s) relating to the desired mix between Audio and Print (otherwise, a solution of only print would result). One possibility is to take the media mix suggested by the preferred matrix and to tranlate it into one or more constraints. For example, if professors indicate that they prefer a situation where there is roughly the same number of audio and print hours, this would translate into the constraint:

(a) A = P

Or, if there is a limit to the permissible number of hours, eg., no less than 200 hours of audio, <u>or</u> no more than 350 hours of print, these would translate into the constraints:

(b) $A \geq 200$

(c) $P \leq 350$

Without running a computer program, the solution to these three problems can be obtained; it is clear that they should be treated as different problems because when two of the constraints (a), (b), and (c) are taken together, the result may be an LP problem with no feasible solution. The solutions are: (a) A =227, P = 227, with a total cost of 21,565 hours; (b) A = 200, P = 254, with a total cost of 21,160 hours; and (c) A = 104, P = 350, with a total cost of 19,720 hours.

As we have seen, these alternatives (excepting the latter one) are feasible on the basis that: (1) there is always an incoming flow of 30 interns per year, ie., that 20,250 man-hours are available per year to work on modularization; and (2) it is acceptable to spend two years to complete the modularization program. However, this is not always the situation. Working with a fixed budget will necessitate substantial modifications to our approach. This is the case, for example, when we can only spend one year for modularization because of a time-limit expressed in a grant-contract, administrative needs of the University, or some other reason like a change in the internship regulations.

- OPTIMIZATION: MAXIMIZATION OF INSTRUCTIONAL MATERIAL UNDER A FIXED BUDGET.

Another approach has to be taken when a fixed budget is a constraint. The problem is then to investigate what is the maximum we can get with that fixed budget. In other words, how many of the 454 hours of instructional material can we get with a fixed budget of only 20,250 man-hours?

If other conditions are held, this problem can be formulated as the following LP problem:

$$\text{Maximize } Z = TV + A + ST + P + CAL + SG$$

Subject to:

$$TV \geq 3$$
$$A \geq 19$$
$$ST \geq 20$$
$$CAL \geq 12$$
$$SG \geq 8$$

$$300\,TV + 55\,A + 100\,ST + 40\,P + 400\,CAL + 400SG \leq 20250$$

$$A \leq 60$$

$$P \leq 300$$

The solution to this problem is shown in Table 6

TABLE 6

OPTIMAL VALUES OF MEDIA HOURS. PARTIAL MODULARIZATION USING EIGHT MEDIA.

MEDIUM	HOURS
TV	13
A	19
ST	20
P	133
CAL	12
S/G	8

Z = 205

The main change in this formulation, with respect to the former one, is that the objective function and one constraint have been interchanged. It is well known that in any mathematical programming problem a change in the formulation may well lead to a solution that is different in terms of the optimization of the real problem. In this case the solution shows this variation. While in the former formulation a two-year plan would suffice to complete the modularization, in the present case it would not.

However, if the budget is fixed there is no other alternative than to plan with the figures obtained. Obviously, the alternative of dividing the 205 hours among the different courses would produce only partially modularized courses. This would result in a reduction of course-hours for the professors, but the Department could not count on having a single tele-education course as such. Instead, the policy should be to select a number of courses to be completely modularized with this budget. For example, compulsory courses 2 to 6 require a total of 201 hours of media-based modules; they can thus form a subsystem which can be completely modularized in a year. Using the algorithm in Appendix A, the reassigned matrix for this subsystem is obtained and shown in Table 7.

TABLE 7

PREFERRED AND REASSIGNED MEDIA-MIX MATRICES. PARTIAL MODULARIZATION USING EIGHT MEDIA.

ORIGINAL MATRIX

MEDIA / COURSE	TV	A	ST	P	CAL	SG	Tot.
2	5	-	6	18	8	-	37
3	7	8	5	13	3	3	39
4	7	7	-	13	-	8	35
5	-	-	-	25	15	5	45
6	7	10	-	16	8	4	45
TOTALS	26	25	11	85	34	20	

REASSIGNED MATRIX

MEDIA / COURSE	TV	A	ST	P	CAL	SG	Tot.
2	2.0	-	10.2	22.5	2.4	-	37.0
3	3.2	5.3	9.7	18.6	1.0	1.1	39.0
4	3.9	5.6	-	22.2	-	3.4	35.0
5	-	-	-	37.8	5.3	1.9	45.0
6	3.9	8.1	-	27.9	3.3	1.7	45.0

NOTE: TV: video-cassette; A: audio-tape; P: printed material; CAL: computer-assissted-learning; SG: simulation/game; Tot.: total hrs. per course;
Numbers are rounded-off to the first decimal place.

- PLANNING LRC'S REQUIREMENTS

Once the figures have been produced of what the system would look like upon completion of the chosen alternative, the planner is concerned with forecasting the resources required by a Learning Resources Centre (LRC) for its implementation.

The first assumption is that printed materials will be distributed to each student. Packages of lessons or single modules can be kept on reserve or in a library on campus; however, it would be recommended that a library system not be the only means of access to materials for the students as the savings derived from a small reproduction of materials run would not offset the costs in special facilities needed for an effective library service. The cost of these modules could be borne, at least in part, by the students since in many instances the modules will partially negate the need for textbooks. As well, a library arrangement would create undesirable and unnecessary limitations on the portability of printed modules.

In the case of only printed and audio lessons one can assume that an LRC as such is not necessarily needed as commercial cassette players are available to almost any student in a University. However, when other media are involved an on-campus operation has to be assumed as a first step in the implementation of a tele-education system. Further research would be needed if establishing off-campus LRC's is sought in order to assess for (a) their number (in terms of budget and students/clients available), (b) their location, and (c) the population served by each of them.

In the following section the planning of an on-campus LRC is discussed. Similar analyses could be undertaken for off-campus operation once the data for each LRC is known.

A second assumption is that audio and slide tape modules can use the same facility; ie., a carrel with a ST projector can serve equally well as a tape player. Hence, the LRC is planned as a four channel (TV, ST/A, CAL, and SG) queuing system.

Once the modularization program has been implemented, the input to the system will be 30 students per year. In the most demanding situation the students will constitute a relatively "compact" flow; in other words, although we can expect that students will go through modules at such different paces as to be noticeably dispersed by the end of the course, in the "worse" situation (ie, the one demanding the most from the LRC's capacities) the students would go through the same module at roughly the same time, and they will be the only students using these modules at that time.

In the case of a complete modularization, from the total of 454 hours of instruction thrugh media, 300 were assigned to Print, 13 to TV, 121 to S/T or Audio, 12 to CAL, and 8 to Sim/Games. Let us assume that the average length of each module of TV, ST/A, CAL, and SG are 30 minutes (0.5 hours), 15 minutes (0.25 hours), 24 minutes (0.4 hours), and 30 minutes (0.5 hours) respectively. Service rates are computed as the reciprocals of these times (in hours), and expressed in customers (students) served per hour. Total number of TV, ST/A, CAL, and SG lessons is

(13 / 0.5) + (121 / 0.25) + (12 / 0.4) + (8 / 0.5) = 556,

of which 26 (4.7%) are TV, 484 (87%) are ST/A, 30 (5.4%) are CAL, and 16 (2.9%) are SG; Table 8 summarizes these data.

TABLE 8

SUMMARY DATA FOR QUEUING MODEL. LRC FOR COMPLETE MODULARIZATION PLAN.

MEDIA (channel)	# OF SHOWS	AL	ST	SR	% OF TOTAL
TV	26	30	0.50	2.0	4.7
A/ST	484	15	0.25	4.0	87.0
CAL	30	24	0.40	2.5	5.4
S/G	16	30	0.50	2.0	2.9
TOTAL	556				

NOTE: AL: Average Length in minutes

ST: Service Time = AL expressed in hours

SR: Service Rate = 1/ST

When determining the number of carrels required for each of the four channels of the system, a maximum waiting time for each channel has to be established; let it be six minutes (0.1 hours). With the formulae (Mitchell, 1980, Chapter 7):

$$WT = QL / AR$$

$$QL = AR^2 / (S \times SR) \times (S \times SR - AR)$$

one obtains

$$QL x S^2 x SR^2 - S x SR x AR x QL - AR^2 = 0$$

Solving for the number of carrels (S), this yields

$$S = (B \pm SQRT\{ B^2 - 4AC\}) / 2A$$

where

$$A = SR^2 xQL = SR^2 xWTxAR = SR^2 x0.1xAR$$

$$B = -SRxARxQL = -SRxWTxAR^2 = -SRx0.1xAR^2$$

$$C = -AR$$

Given that all of the constants are positive real numbers, it follows that there will be only one positive answer for S — the one corresponding to the addition in the formula for S.

Arrival rates are calculated as follows. There will be a total of 556 lessons per term or, assuming a 15-week term, 37 lessons per week. With a five day week, this figure translates into an average of 7.4 lessons per day. With the LRC open at least eight hours per day, it should not have to contend with more than 0.9 lessons per hour. Given that the most the system should serve is 30 students (and this assumes maximum enrollment in all courses), then there will be no more than 27 demands per lesson per hour. These demands would be distributed on the average to TV 4.7% of the time (1.27 demands per hour), ST/A 87% (23.49), CAL 5.4% (1.46), and SG 2.9% (0.78).

The final solution is obtained by using these data in the equation for $. The results are presented in Table 9. Figures suggest that the LRC be composed of 2 carrels with a Video-Cassette Player, 8 carrels with ST projector, 2 carrels with a CAL terminal, and 2 rooms for Simulation/Games.

TABLE 9

REQUIREMENTS FOR LRC. COMPLETE MODULARIZATION PLAN.

CHANNEL	AR	AQL	S
TV	1.27	0.148	2 (1.257)
ST/A	23.49	2.026	8 (7.764)
CAL	1.46	0.120	2 (1.264)
SG	0.78	0.047	2 (1.215)

NOTES: AR: Arrival Rate (demands per hour)

AQL: Average Queue Length (in # of customers=students)

S: Servers (Rounded-off number of carrels required; actual numbers in parentheses)

A similar analysis can be performed in the case of a partial modularization (ie., when modularizing only courses 2 to 6). From the total of 201 hours of instruction 129 were assigned to Print, 13 to TV, 39 to ST/A, 12 to CAL, and 8 to SG. Average module lengths and, thus, Service Rates are the same as before. The total number of lessons is now

$$(13 / 0.5) + (39 / 0.25) + (12 / 0.4) + (8 / 0.5) = 228$$

of which 26 (11.40%) are TV, 156 (68.42%) are ST/A, 30 (13.15%) are CAL, and 16 (7.03%) are SG. Arrival rates are calculated as indicated before. Using the equation for S yields the results presented in Table 10. In this case the LRC should be composed of 2 TV, 4 ST/A, 2 CAL, and 2 SG carrels.

TABLE 10

REQUIREMENTS FOR LRC. PARTIAL MODULARIZATION PLAN.

CHANNEL	S
TV	2 (2.002)
ST/A	4 (3.389)
CAL	2 (1.878)
SG	2 (1.631)

NOTE: S: Servers=Carrels (Rounded-off number of carrels required; actual numbers in parentheses)

CHAPTER 6: DISCUSSION

The value of the model offered here for the educational systems analyst and planner is self evident, as is also its conceptual importance. Suffice it to say that besides the work done by Mitchell (1980) and Brassard et al (1980), no reference could be found in the literature that dealt in a quantitative way with the problem of planning the transformation of a conventional educational system into a system of tele-education (ERIC search done in May 1980).

However, the information needs for the input to this model deserve some discussion. Inputs are the production costs per instructional medium, the original media selection in the instructional design program, and considerations about global media mix and the maximum and minimum hours of instruction per media. The information needed to satisfy these input requirements concerns costs of instructional media and media selection. A review was made in Chapter 4 of the little relevant literature available. As a conclusion, there is a tremendous need for more educational research in these topics.

Research in learning styles should be directed to assist in the development of media programs for tele-education systems. First, media selection for self-instructional modules should be a function of the cognitive styles for which the instruction is aimed. As well, similar research should shed light on the topic of media mix for a tele-education system. This latter problem influences the model proposed in this thesis in its optimization step: in order to minimize costs or maximize media hours produced only considerations about the desired global media mix are used. However, the reassignment algorithms operates on a preferred media matrix, where the aforementioned problem of selecting media for the particular instructional modules has a major influence. Thus far, the studies conducted on the reassignment algorithm seem to indicate the dependence of its convergence on the initial state. In other words, the reassigned matrix depends not only on the values imposed for columns and rows, but also on the original media selection data given in the "preferred" matrix.

The optimization step in this model involved the use of LP models since linearity of media production costs as well as in the global media-mix constraints was assumed. However, these assumptions are indeed very strong ones that could probably not resist a very strict analysis. If production costs can be quantified at least in an interval scale, and if the source of non-linearity is identified, other OR techniques can be used instead of LP in the optimization process without modifying substantially the whole approach. However, as was indicated in Chapter 4, a literature review of instructional media production costs showed few relevant references, all of them being rather non-quantitative in nature. It was stated above (Chapter 4) that this is an indication of the difficulty found in quantifying production costs: they can loosely be ranked in an ordinal scale, but quantitative statements are not likely to be generally valid since production costs may depend on intrinsic characteristics of the producer or production group.

Two alternatives arise at this point. The first one, adopted in the development of the model offered here, is to rely on assessments by people with experience in working with similar production groups, and to manage those assessments as target figures. It is recommended, however, to include a continuous reassessment of production costs in the ongoing evaluation of the production program, in order to either correct for deviations or modify the input figures in the model. For example, if interns start investing 55 hours to produce an hour of printed material, an investigation should be made aiming to determine if this constitutes a "spurious" deviation (because of the specific material contents, human relations problems in one or more groups, etc) which should then be corrected in order to return to the preestablished figures; or a characteristic of the production group, in which case it has to be inputted to the model, and the new figures run again in order to obtain a more accurate plan.

The second alternative is to develop a model considering that production costs cannot be determined in the way assumed in this thesis. Future development should be directed to produce models where production costs of instructional media are either measured in an ordinal scale (ie., where only a ranking can be made) or treated as random variables (with either known or unknown distributions). It seems to me that these possible developments, which will require more sophisticated stochastic OR techniques, have great potential for use in tele-education systems planning and development.

The model offered here is a deterministic model to represent a course of action for transforming an educational system organized under a conventional scheme into a tele-education system. However, within this course of action many decisions have to be made, with the effects of them on the innovation's implementation assessed by means of simulations. In order to stress the relevance of this procedure, an effort was made to relate it to a real situation by using data that could represent an actual system. A situation similar to that of the Graduate Programme in Educational Technology at Concordia University was studied. As a result of the subsequent analysis, the following findings and recommendations are submitted.

A) Internship program. The establishment of an internship program integrally tied to the conception, planning, production, and evaluation of the course material would result in an improved learning experience for the students in the Programme. The educational as well as professional experiences that such a structured program can give to the potential Graduates, however, should not end with the modularization of the Educational Technology Programme. The modularization idea could be "sold" for the benefit of future students entering the internship program, to other Departments within the University or to any Instructional/Training system wanting to move into the tele-education scheme. Students would definitely benefit from the experience of working in an educational/intructional systems development group, an idea praised but seldom practiced in the actual system; and certainly one that would better prepare students for their future professional practice as Educational Technologists.

B) Faculty time. Completion of the modularization program proposed would give more time per professor for activities other than those concerned with the delivery of courses. This time, however, should be invested in R&D and in the establishment of a tutorial program which, as has been stated above, is an integral part of any successful tele-education development. If the Department wishes to increase its enrollment from 30 without sacrificing research time and/or thesis supervision time (and the quality of work which this ensures), the only solution is to increase the number of faculty. The effort that thesis or thesis-equivalent supervision demands from a faculty member, as was pointed out above, places a ceiling of 5 students per professor. If a more dramatic increase is sought, a modification of the thesis supervision procedure must be contemplated; for example, allowing students to work in groups and/or to be supervised by other than full-time faculty. Of course, adequate safeguards would have to be instituted to ensure that quality is not compromised.

C) Analysis of alternatives simulated. The advantages of a complete modularization two-year plan utilizing all eight media are evident when compared to complete modularization utilizing only audio&print. The former requires between 12,000 and 14,000 man-hours more to produce (ie, 18 to 21 extra interns) and an LRC should be implemented to house its courses. But for some learning styles, and for some kinds of learning, the absence of stimuli like the ones provided in TV, ST, CAL (provided it is not used as a mere page-turner), and SG lessons is crucial for the learning outcomes. Contrary to models like the UK's Open University one, media other than print are given the task of conveying instructional messages to the student which are not provided elsewhere, and which are essential to the instructional process. In other words, none of the eight media considered in the model is supposed to carry only superfluous, supplementary, or even supporting instructional communication.

The partial modularization one-year plan requires, too, the implementation of an LRC whose characteristics are very similar to the one needed in the complete modularization plan. The latter would require only 4 extra carrels for Audio/ST programs. If the constraint of a limited budget (ie, one year time-limit for the production program) was not present in the actual situation, the complete modularization plan would be favoured under any cost-effectiveness argument.

A few words can be said about the implementation and management of a tele-education system, although these topics are beyond the scope of this thesis. Concerning the costs of reproducing media-based instructional material, excellent work has been produced by Dean T. Jamison (cf, Jamison, 1977; Jamison et al, 1978) in which he provides models to forecast those costs as well as examples of their application in projects carried out in some developed and developing nations. Although much more restricted, Rosenquist's (1975) analysis considers some factors relevant to the production of written material which are not part of Jamison's discussion.

The organization of a system of tele-education, on the other hand, has been discussed by: Anand (1979), Chang Min Phang (1975), Erdos (1975, 1976), Haefner (1975), Holmberg (1977), McD. Mitchell (1975), and Singh (1975); specifically concerning the UK's Open University, Hawkridge (1978), Harrison (1980), McIntosh et al (1977), and Perry (1975) provide a good overview of that system.

At present I have recognized one flaw, concerning the output of the reassignment algorithm, in the model I propose in this thesis. Conceptually, the reasignment algorithm is a method aimed at a "democratic" proportional distribution of the optimization output (viz, of the optimal set of media hours). However, the result may not always be satisfactory, from an educational point of view, for the component subsystems. For example, suppose that a professor who has asked for 2 hours of TV and 10 hours of Print is told that s/he will instead be given one half hour of TV and 11.5 hours of Print. This may prove to be far from an optimal situation from the instructional designer's point of view. Given that s/he will not obtain the complete 2 hours of TV, it may well be that s/he would rather not use that medium at all. The situation is still worse if the output is some weird number such as "0.78 hours of Audio"; would this mean that Audio lessons should be produced for that course adding up to exactly 46 minutes and 48 seconds? Certainly not.

The reassigned matrix is rather a framework, a starting point from which to negotiate what the actual distribution will be of the total number of hours through each of the media among the different courses. This negotiation of the actual instructional development, however, has to be undertaken by professors seeking to optimize their instructional systems within the framework and limits provided by the optimization of the larger system. If as a result of those negotiations the media matrix is modified in such a way that, say, an extra 2,000 man-hours are required in the production program, no wise educational systems planner, developer, or administrator would reject this increase as it is still affordable. But if the modification performed make a substantial increase, an effort has to be made to settle differences while trying to make professors more conscious about their participation in a larger system.

As is advanced above I envision the existence of at least two different and complementary perspectives from which a design for a tele-education system should be optimized. On the one hand, the system as a whole is subject to administrative, socio-economic, as well as political, constraints. I have dealt in this thesis with a possible way of optimizing a design from the macrosystem's perspective. To these ends I have translated this into the problem of either minimizing production costs under a set of "educational" constraints, or maximizing the "availability" of instructional materials under a fixed budget. In either case an additional set of considerations concerning instructional design decisions was introduced, perhaps making the whole approach questionable until a more definite knowledge about the microsystems is available.

This brings us to the second perspective. As I also pointed out above, an educational technologist is concerned with the optimization of instructional processes, ie, with the optimization of processes which occur in the component subsystems of a tele-education one. For example, one can ask questions like "Which is the best way of making student 'X' learn 'Y'?", that may be broken down into other questions, like "What is the minimum 'effort' (time, strategies, resources, etc) needed to make student 'X' learn 'Y'?", or "Which is the maximum learning that student 'X' can obtain when trying to learn 'Y' under a given 'effort'?"

To date there is no definite answer to any of these questions; nor is there a positive indication that there can, or cannot, be one. In the field of instructional design much more research has to be done if a knowledgeable, scientific, and systematic effort towards the optimization of the processes that occur in the microsystems is sought. As Daniel (1980) states, the challenge is there for educational technologists:

> As mobility increases and life-styles continue to diversify more and more people will seek courses and programs offered in a manner convenient to their schedules and place of residence. Only the combination of a systematic approach to the design of learning experiences coupled with the use of appropriate communications technology will allow institutions to meet those needs.

NOTES

(1) For a review of the applications of OR techniques (and in particular of LP) in Educational Planning, see Vazquez-Abad, J. Mathematical Models in Educational Planning. Unpublished manuscript, Concordia University, Department of Education, April 1980.

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APPENDIX A

A REASSIGNMENT ALGORITHM

(Adapted from Brassard et al, 1980, Appendix 2)

This appendix deals with the development of a method for reassigning a media-mix matrix. The procedure used will be discussed with specific relation to the problem dealt with in this thesis, but is both applicable to and useful in a wide variety of similar situations. A simple interactive computer program has been written which can be used for any application of this method.

Problem: When in the process of introducing media into an educational program, different media (TV, S/T, P, CAL, etc.) Are available. The media assignment is usually made by the instructor(s) in consultation with a media expert based on educational criteria. Three decisions must be made for each of the N number of courses in the program: 1) the percentage of each course to be offered through media; 2) which media will be used in each course; and 3) the number of hours of instruction assigned in each course to the various media. With this information, a media-mix matrix may be constructed. By assigning each row to a different course (1,...,N) and each column to a different media (1,...,M), the result is a matrix consisting of N rows and M columns. The (i,j) element in the matrix represents the number of hours of instruction in course #i using media #j.

However, constructing such a matrix using only educational considerations could quite conceivably result in a practically unfeasible proposal. Costs, in terms of materials and/or time, could render realization of the "ideal" matrix impossible. Budgetary constraints must modify the educational decisions first taken. The problem then becomes one of priorities, and what usually happens is that the optimal accounting media-mix is crudely superimposed onto the original matrix by modifying each element by the percent change per column. This, however, ignores the original educational decision as to the desirable number of hours per course to be given over to media.

Objective: The objective of this algorithm is to modify the media-mix matrix (ie, to reassign the hours of instruction in each medium for each course) given the feasibility restrictions which impose new totals for each column while respecting the original educational decision as to the total number of hours of instruction that will be offered through media in each course (ie, maintaining the total of each row).

Method: The method proposed is an iterative computational one. The following notation will be used:

X_{ij} is the (i,j) element in the matrix; that is, the number of hours of instruction in course #i that is offered through media #j (i=1,...,N; j=1,...,M).

A_j is the total number of hours required of media j in all N courses; thus, $A_j = \sum_{i=1}^{N} X_{ij}$, $\forall j$ (1)

C_i is the total number of hours in course #i that will be offered through media;
thus, $C_i = \sum_{j=1}^{M} X_{ij}$, $\forall i$ (2)

The new policy establishes a new value for A_j ; therefore, equation (1) will not necessarily hold after the new policy is implemented. Let us call B_j the actual sum in equation (1).

$$B_j = \sum_{i=1}^{N} X_{ij} , \quad \forall j \qquad (3)$$

We will assume further that the new policy has not changed the total number of hours of instruction that will be offered through media. Thus,

$$\sum_{j=1}^{M} B_j = \sum_{j=1}^{M} A_j = \sum_{i=1}^{N} C_i = T.$$

If for each column j we define E_j as being the quotient A_j/B_j, and multiply the elements X_{ij} by E_j, the result is:

$$X'_{ij} = X_{ij} * E_j = X_{ij} * A_j / B_j \tag{4}$$

Now in each column, the following is true. (The next-to-last expression is obtained from equation (3)).

$$\sum_{i=1}^{N} X'_{ij} = \sum_{i=1}^{N} X_{ij} * A_j / B_j =$$

$$= (A_j / B_j) * \sum_{i=1}^{N} X_{ij} = (A_j / B_j) * B_j = A_j$$

However, after this transformation with its resulting new X'_{ij}, equation (2) will not necessarily work. Therefore, let us assign D_i the new value for the sum of the row elements in equation (2) such that:

$$D_i = \sum_{j=1}^{M} X'_{ij}, \quad \forall i \tag{5}$$

In each row i we define F_i as the quotient C_i/D_i and multiply the elements X'_{ij} times F_i, resulting in:

$$X''_{ij} = X'_{ij} * F_i = X'_{ij} * C_i / D_i \tag{6}$$

In each row, then:

$$\sum_{j=1}^{M} X''_{ij} = \sum_{j=1}^{M} X'_{ij} * C_i / D_i =$$

$$(C_i / D_i) * \sum_{j=1}^{M} X'_{ij} = (C_i / D_i) * D_i = C_i$$

Transformation (6) will, however, change the matrix elements so that equation (1) will not necessarily be true. If one repeats the entire procedure, new values will result for the matrix elements, and successive iterations will produce closer approximations to the solution sought. Because of its iterative nature, the procedure should be stopped when an acceptably close result is obtained. The criterion for deciding what is acceptable can be varied; for this problem the criterion related to how close the rows and columns approached quadratically the target numbers. That is, if an upper limit ϵ for the error allowed is assigned, the iterative procedure is stopped when:

$$(A_j - B_j l)^2 < \epsilon^2 \text{ AND}$$

$$(C_i - D_i)^2 < \epsilon^2$$

A very simple interactive computer program was written in FORTRAN IV-PLUS following the method described here. It was implemented in the CDC-6000 CYBER-174 at Concordia University, and was used to obtain the reassigned matrices of this thesis. A listing of the program is available upon request.