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A Mathematical Model for Curriculum Planning

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***Abstract*—** At the University Eduardo Mondlane (UEM) curriculum, the basis of education, are devised by the members of Faculty Council, according to their own concept of what is best, from their own outlook and at their level of knowledge. The curriculum reform has been a continuous process within the university for over 50 years of its existence and this process is conducted under the guidance of the "Pedagogical Directorate". However, the academic units, like Faculties and Departments, enjoy a large degree of autonomy in designing and developing their own curricula, usually in conjunction with other departments or faculties to which they are related. In this article we propose a Mathematical Model for Curriculum Planning (MCP) based on the concept of matrix.

Keywords- *Mathematical Model, Curriculum Development, Curriculum Planning, Linear Curriculum, Spiral Curriculum, Pyramidal Curriculum, Matrix.*

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I. Introduction

Some change in education is inevitable in response to an ever-expanding body of knowledge and advances in technology. However, often, academic units do little more than tinker with the timetable to appease colleagues, but with little real effect on. Successful innovation and change in the way university students are prepared are notoriously difficult. The requirements for a successful change are a well-defined philosophy, with reasoned justification, and an adequate consideration of consequences. Since de curriculum is a system of interrelated components, any change in one component will have repercussions on others. While some effects may benefit the system, others may have detrimental consequences. Thus, it is important to be aware of the effects of any significant innovation on all components of the system, so that appropriate and timely responses can be made.

Despite an extensive period of educational activity, in which resources on an unprecedented scale have been available for curriculum reform, the concept of curriculum remains disturbingly vague. For most of the faculties at UEM, curriculum was synonymous with syllabus, and meant nothing more than a list of content topics.

There exist two major ways of defining within current educational literature, each with its own group of adherents. One group as a body of knowledge that is divided by discipline matter and complexity according to the ability levels of the students who, moving through the divisions in order, will master the whole body of knowledge by time they finish school. This camp sees curriculum eroded by the other group: educational technocrats, who replace the emphasis on knowledge with one on methods and form.

A curriculum can be defined as:

"*a systematic group of courses or sequences of disciplines required for graduation or certification in a major field of study*".

II. Overal Curriculum Struture

We shall first consider the question of sequence, as it is one of the first aspects of the instructional design to become defined as the process of analysis progresses.

A. *The Linear Curriculum*

An overall curriculum structure may commence to emerge at this stage. Most commonly, a linear curriculum structure is adopted, but we shall see that there are several alternatives. A linear structure is most justified in the case of objectives which are closely related to each other sequentially and which are "obligatory learning" (as in the case of job-related training). In such a case the final jobs or tasks to be performed after training, is made up of separate sections, each one producing an input to the next.

B. *The Spiral Curriculum*

In such a case, the overall structure of the main objectives may already suggest that there is not one answer – that, some rules of sequence construction must be taught early while others can wait, and indeed depend on prior teaching of some rules of punctuation. Thus, one wishes to treat a topic at a relatively shallow depth, then study another topic and later come back to the original topic. This gives rise to the concept of the spiral curriculum.

It is useful, early in design process, to identify the overall structure that the course will probably take on, as this will influence later analysis and design decisions. In the case of adopting a spiral curriculum model, for example, one will need, at specific level of analysis, to examine very closely the interrelationships between the objectives in different topics, in order to ensure that all the detailed objectives of a specific topic which are prerequisite of the learning of the other topic are so sequenced and divided that they are both an acceptable sequence of teaching the first topic and at the time are always being achieved ahead of the related objectives of the following topic. However, the adoption of a spiral curriculum structure in a course of any size involving several instructional designers or teachers requires a higher level of coordination and teamwork in the early stages of design.

C. *The Pyramidal Curriculum*

Other curricular "shapes" one may opt for, include the "pyramidal". This shape intends to communicate that a course has a common base that al students will study and that later they tend to specialise in one or more specific areas. This shape is not perhaps as useful in conceptualising a whole curriculum. It communicates rather the type of that one particular student might follow. When used to conceptualise the several options, one may be led to start talking in terms of "multi-peaked pyramids".

Most of the discussions on curriculum changes centre on the "what" and "when", with some attention to the "why". This paper is concerned with the "how", a problem that is often treated as straightforward, despite all the evidence to the contrary. A brief review of historical evidence reveals that there is no established effective method of planned curriculum change. How might one do better? Here a "Mathematical Model" as a scientific approach based on the concept of matrix is forwarded for curriculum design and evaluation.

III. THE MATHEMATICAL MODEL FOR CURRICULUM PLANNING

The basic idea of a mathematical model for curriculum planning (MCP) consists in representing every discipline of the curriculum as a matrix. For instance, let us suppose that a curriculum has n disciplines D_1, D_2, …, D_n and,

$$D_i = \begin{pmatrix} e_{i1} & e_{i2} & \cdots & e_{im} \\ s_{i1} & s_{i2} & \cdots & s_{im} \end{pmatrix}, \; i = 1, 2, \ldots, n$$

There, every column of the matrix is reserved to one of notion that can be introduced and studied in this discipline. In this case, such a notion is an output of this discipline and the correspondent variable $s_{ij} = 1$. By the contrary, if a notion for which the column k is reserved has not been treated in this discipline or has been used but is not a direct result of it, the correspondent variable $s_{ij} = 0$. In the same way, if a discipline need some notions as basic requisite for the students to study a new discipline, the correspondent value of $e_{ij} = 1$. If there is no need to know any notion for which the column k is reserved to study this discipline, then $e_{ij} = 0$.

Thus, elements of matrix D_i are 0 or 1 depends of the situation described above. The first row we will call input row and the second row- output row. Of course, to create such a matrix, we have to provide a list of all the notions studied in the given course and this is a great deal.

After describing such a way, in every discipline we need to put them in certain order to obtain an optimum curriculum. To define what we understand as an optimum curriculum, first, we introduce a notion of adjustment of two disciplines and adjustment of n disciplines.

Definition 1: Let us given two disciplines,

$$D_i = \begin{pmatrix} e_{i1} & e_{i2} & \cdots & e_{im} \\ s_{i1} & s_{i2} & \cdots & s_{im} \end{pmatrix},$$

and,

$$D_l = \begin{pmatrix} e_{l1} & e_{l2} & \cdots & e_{lm} \\ s_{l1} & s_{l2} & \cdots & s_{lm} \end{pmatrix}.$$

Adjustment A_{il} is,

$$A_{il} = \sum_{k=1}^{n} s_{ik} e_{lk}$$

$$A_{li} = \sum_{k=1}^{n} e_{ik} s_{lk}$$

<u>*Properties of Adjustment*</u>

P1. In general case $A_{il} \neq A_{li}$

P2. $0 \leq A_{il} \leq m$ is a integer number

P3. If $A_{il} = A_{li} = 0$, the discipline D_i and D_l are independent

P4. The larger value of adjustment A_{il} means that more output notions of discipline D_i serves as input material for discipline D_l.

P5. If $A_{il} > A_{li}$, it means that discipline D_i must be in front of discipline D_l in the curriculum.

Now, let us consider three disciplines D_1, D_2, D_3. It is possible $3! = 6$ permutations of these disciplines and as a result, six different curricula.

$D_1D_2D_3$, $D_1D_3D_2$, $D_2D_1D_3$, $D_2D_3D_1$, $D_3D_1D_2$, $D_3D_2D_1$.

In a natural way we may define the adjustment of every permutation (curriculum) as

$$A_{ijk} = A_{ij} + A_{ik} + A_{jk},$$

where i, j, k are indices of disciplines of the curriculum $D_iD_jD_k$.

Now, let us consider a whole curriculum of n disciplines as a permutation, D_1D_2 … D_m, there exist "m!" such permutations and as a result "m!" curricula. Though, we need to consider two things:

1. To develop a criteria by which we can evaluate an existing curriculum.
2. To develop an algorithm that permits to choose an optimum curriculum from "m!" possible curricula.

As a first step, we define adjustment of an arbitrary number of disciplines or, which is the same, adjustment of any curriculum, as

$$A_{i1,i2,\cdots,im} = \sum_{\sigma} A_{ik},$$

Where, sigma extends on the set σ of C_m^2 combination of two indexes in such a way that the second index is larger than the first one. This number serves for a numerical evaluation of quality of a curriculum as a whole. It is a function on the set P_m of permutations of disciplines and being limited admits a maximum in this set.

Let us call optimum curriculum as a permutation of disciplines for which,

$$A_{i1,i2,\cdots,im} = \sum_{\sigma} A_{ik} \,,$$

is maximum. And, the number

$$A_0 = \max_{i1,i2,\cdots,\cdots im \in P} A_{i1,i2,\cdots,\cdots im} \,,$$

we will call as the optimum adjustment of a given curriculum.

The coefficient

$$Q = \frac{A_{i1,i2,\cdots,im}}{A_0}$$

we will call quality of a given curriculum.

It is clear that $0 \le Q \le 1$ and it opens the way to express the quality of a curriculum in per cent. Thus, the problem of developing an optimum curriculum in the frame of our criteria of optimisation is formalised in a mathematical way and reduced to a well-known problem in the optimisation theory – optimisation in a set of permutations. Now, as said by Leibnitz, *there is no discipline for a long discussion, let us sit and count*.

The proposed model permits not only to create an optimum curriculum and to evaluate the existing one but the MCP can also be used for judgement of the quality of a curriculum. The optimum adjustment of a curriculum, as we have yet defined, depends on the disciplines that formed the curriculum and the contents of these disciplines. They serve as a system of restriction for optimisation problem. The model opens the way to detect weak points of a curriculum and change it in such way to increase optimal adjustment. For this purpose we introduce a new concept of *weight of a notion*.

Definition 2: Let us call weight of the j-notion

$$p_j = \sum_{k=1}^{m} e_{kj} \,, \quad j = 1,2,\cdots,n$$

It means that the number of entry of a given notion is the input material to the learning of the next discipline. If the weight of a concept is 0 it will be revised the necessity of this notion is the discipline. If such a necessity provides the needs for a proper discipline, the detected notion stays in it, in the contrary, that notion must be omitted. In any case, such an analysis will impulse the pedagogic staff from time to time to revise the contents of every discipline with the aim to achieve an organic unity of the curriculum, put the end to isolation of discipline and do all the process of preparation as a whole.

IV. General Criteria Proposed For Sequencing In MCP

To implement the MCP the following general proposed criteria must be taken into account:

- From simple to complex, implying that the simpler to learn discipline matter should be taught first, or that new ideas should be introduced by simple examples and applications first
- From known to unknown, implying that learning should be so planed as always to commence from a concept or procedure that the learner has already mastered and expanding his abilities by carefully building on this base.
- From particular to general, implying those general principles should introduced by means of examples first
- From concrete to abstract, overlapping in one sense with the previous rule but also being taken in the sense implied by the viewpoints of Piaget, Bruner and their followers, concerning the learning cycle of concrete experiences followed by generalisation in abstract terms and back to more concrete experiences.

In addition there are some general purposes tactics for instruction in practical tasks. These include:

- The progressive parts method of sequencing the practical exercises for a task made up of a series of sequentially linked stages.
- The cumulative parts method, which organises the sequence and structure of the exercises somewhat differently.

The backwards chaining method, which is the inverse of cumulative parts method.

V. Conclusions

A curriculum evaluation process needs planning and steering. It may be initiated and organised more or less at levels of policy and decision makers at the university as a whole, and involving the faculty and the department levels, or even the individual teacher, depending on the unit of analysis and the decisions to be made. And, how the evaluation process will actually be responsible for the evaluation can depends on the local circumstances. However, some conditions must be met to guarantee that teachers will be accepting to change programmes and programmes as a result of evaluation activities. Then, because a curriculum normally is designed and implemented at the level of a faculty or department, a steering committee must be installed at that level. The task of steering committee are planning and supervising the evaluation activities of the curriculum. And, the evaluations must be conducted by workgroups.

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