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Methodology Article

The Application of Systems Methodology to Curriculum Development in Higher Education

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Abstract: The development of curricula is a major priority of educational systems. The associated concepts, theories and guiding principles are briefly presented in this paper, along with a systemic approach for designing a curriculum. This approach is based on the systemic domain of Systems Methodology that facilitates curriculum development in a holistic manner. The related systemic guiding principles are demonstrated through examples that are presented according to the relevant modelling technique of Organizational Method for Analyzing Systems.

Keywords: Systems Methodology, Curriculum Development, Systemic Modelling

1. Introduction

The curriculum is the "strategic plan" of educational activities. Either in a centralized educational system or not, curriculum development constitutes a major priority, since it dictates the daily actions of every educational organization. The curriculum describes an educational process and in this respect the notion is applicable to extra-curricular activities, as well [1]. General concepts, theories and designing principles are available for developing a curriculum, being also a course of formal teachers' training [2]. The adequacy of educators in designing curricula is even more important in decentralized educational systems, where the responsibility of educational activities resides heavily in the individual educator, while this responsibility is the normal situation for tertiary education.

In this study, curriculum development, being perceived as a meta-process, is designed via systemic thinking. It is called a meta-process because a curriculum describes a teaching-and-learning process [3], while its development is also a process, alike, which designs the initial teaching-and-learning process. Systems Inquiry, which consists of the three related domains of Systems Theory, Systems Philosophy and Systems Methodology [4], is probably the most comprehensive systemic conceptual tool for designing a process, in general. It has been already proposed for educational systems [5], where especially Systems Methodology can be used to facilitate curriculum development in a holistic manner, as it will be proposed and demonstrated herein.

2. Related Framework

According to Kerr (in [3]), a curriculum is "All the learning which is planned and guided by the school, whether it is carried on in groups or individually, inside or outside the school." The usual frameworks of curriculum development that are encountered, especially in post-secondary and tertiary education, can be classified as follows [6]:

- Broad Fields curricula (multi/inter-disciplinary) that are developed to emphasize the relationships between different fields.
- Inquiry (or Problem) Based curricula that are developed around an area of inquiry or a set of problems. Such a case could be the education of candidate technological teachers and how to learn what to teach and how to teach it [7].
- Discipline (or Subject-) Centred curricula that are developed around specific disciplines or subjects (e.g., see [8]).
- Spiral curricula that are developed around specific skills/concepts, which are introduced and revisited by

the learner as the program of study evolves, for a deeper understanding.

- Experiential curricula that the learner elaborates a set of experiences and then he/she is assisted to draw meaning from them.

The relevant bibliography is of significant extent and broad context. For example, Labastilla [9] presents 21 points regarding concepts, theories and principles for curriculum development, while Ramsey [2] includes 68 relevant references in his teaching work. Nevertheless, a survey of curriculum development methodology is beyond the scope of the present article. Therefore, just a few historical and contemporary approaches will be presented that are easily accessible and indicative regarding these concepts, theories and principles, before the suggested herein systemic approach is demonstrated and related to the existing ones.

2.1. The Model of Taba

In 1962, Taba presented a pioneering model for curriculum development [10]. This approach included a curriculum committee that conducts needs assessments in collaboration with all possible stakeholders (e.g., the educational administration, parent groups of the community and other key groups, teachers, etc.). The original model has been explored and modified to include [2]: a needs assessment, goal setting and selecting content that are afterwards aligned with local instructional objectives, training of teachers, learning experiences, a pilot implementation, a wider school implementation and an on-going evaluation of the curriculum. The overall structure of the curriculum development is perceived as a cycle that is composed of the following steps [2]:

(i) Needs assessment;
(ii) Goal setting;
(iii) Objectives;
(iv) Selecting content;
(v) Organizing content;
(vi) Selecting and organizing learning experiences;
(vii) Implementing the new or revised curriculum;
(viii) Evaluation and recycling.

The Taba's model can be regarded as especially suitable for developing Inquiry Based (2.1. i), Discipline Centred, Spiral (2.1. vii, 2.1. viii) and Experiential (2.1. vi) curricula.

2.2. The Model of Greer

The model of Greer is an approach of *backward design* to curriculum development [11]. A list of major educational goals that are broad and conceptual in nature is initially defined by the teacher and then hopefully attained by the students until the end of the teaching period. The development process is dictated by the following five principles:

(i) *Considering the Learners' Needs*, where the abilities and needs of individual students are taken into account, therefore allowing for differentiation before the designing of the curriculum.
(ii) *Looking at the Timeline*, where the available time for achieving the desired goals is carefully considered.
(iii) *Selecting Lessons and Activities* that can be conducted for achieving the desired goals within the available timeline.
(iv) *Collaboration* between teachers of different disciplines for maximizing the results of the teaching-and-learning process.
(v) *Assessment in Curriculum Development*, which is weekly conducted for making the proper adjustment to the pace and content of teaching.

Because of the explicitly mentioned principle 2.2. iv, the Greer's model can be regarded as very suitable for developing Broad Field curricula.

2.3. The Outcome-Based Model

The Outcome-Based model is structured according to the context of *Outcomes-Based Education* (OBE [12]). OBE is a student-centered and results-oriented approach. The main principles and concepts of an associated curriculum are the following [6]:

(i) The focus of development is on the results of learning that are expressed as outcomes, which are clear and known to everybody.
(ii) Courses and learning experiences are structured to assist learners in achieving the desired learning outcomes.
(iii) Multiple learning opportunities are created to help different types of learners in having activity-based and personalized learning experiences through flexible paths towards the desired outcomes.
(iv) The standards-referenced assessment matches the learning outcomes.

The Outcome-Based model facilitates the development of Experiential curricula (2.3. iii).

2.4. The Inquiry Approach Model

The Inquiry Approach model is based on the main concept that there is not a single way for developing an effective curriculum. Curricula are considered to be dynamic entities that require the usage of strategic questions, a variety of people and various data sources for collecting information that will facilitate optimum development decisions. A simple and not comprehensive list of the related questions is given as an example, which is presented in [6]:

(i) Why is this program needed?
(ii) What are the graduates of this program expected to know and to be able to do?
(iii) Are there standards or expectations from professional associations that need to be considered?
(iv) What credential is appropriate?
(v) How does this program relate to others in this college or elsewhere?
(vi) Who are the learners likely to be attracted to this program?
(vii) What abilities will students entering the program

need to be successful?

(viii) Who are the groups and individuals that should be consulted as this program is developed or revised?

This model facilitates the development of Inquiry Based and Spiral curricula.

2.5. The Integrated Course Design Model

The Integrated Course Design model is a self-directed guide for developing curricula, designed by Dee Fink [13]. The main components of Integrated Course Design are the following:

(i) The analysis of the *situational factors*.
(ii) The formulation of the *learning goals*.
(iii) The designing of the *feedback and assessment* procedures, using the principle of Backward Design (see also: *2.2. The Greer's model*).
(iv) The selection of the appropriate *teaching-and-learning activities*.

This model is related to the *significant learning* and integrated curriculum design approaches [14].

2.6. The Universal Instructional Design Model

The Universal Instructional Design model (UID) is a general guide for developing curricula from the University of Guelph. It consists of the following seven principles, ensuring that instructional materials and activities should [15]:

(i) be accessible and fair;
(ii) provide flexibility in use, participation and presentation;
(iii) be straightforward and consistent;
(iv) be explicitly presented and readily perceived;
(v) provide a supportive learning environment;
(vi) minimize unnecessary physical effort or requirements;
(vii) ensure learning spaces that accommodate both students and instructional methods.

UID was originally developed for learners with disabilities [6].

2.7. The Modelling of Smith

Smith [16] presents an approach to the theory and practice of curriculum development classified in four ways (models):

(i) Curriculum as a body of knowledge (syllabus) to be *transmitted* that is commonly perceived as courses leading to examinations.
(ii) Curriculum as a *product* that is perceived as an attempt to achieve certain outcomes (behavioural objectives) in students [17].
(iii) Curriculum as a *process* that is perceived as an activity linked with the practical form of reasoning (commenced by Aristotle), as well. This model is driven by general principles and emphasizes on judgment and making of meaning.
(iv) Curriculum as *praxis* that makes explicit statements about the interests it serves [17]. It can be regarded as a development of the previous model (2.7. iii).

This approach is influenced by the knowledge categorization of Aristotle into three disciplines [18]: the theoretical, the productive and the practical. The equivalence is:

- the theoretical = the curriculum as a syllabus (2.7. i);
- the practical = the curriculum as a process (2.7. iii) & praxis (2.7. iv);
- the productive = the curriculum as a product (2.7. ii).

Smith also considers the social context of curriculum development, which is rather neglected by the previous categorization, partially according to the work of Cornbleth. In this respect, curriculum is a particular type of process that is "an ongoing social process comprised of the interactions of students, teachers, knowledge and milieu" [19]. Another consideration is the perception of curriculum "as the boundary between formal and informal education." According to Jeffs and Smith [20, 21], the notion of curriculum is very problematic in the case of informal education.

3. A Systems Methodology Approach

A *system* is defined as a complex set of elements (components) with properties, relationships and processes, a notion that in its contemporary form originates from the work of Bertalanffy [22]. The systemic study of social phenomena is influenced by the works of Parsons [23] and Luhmann [24]. The main features of social systems are that:

- they are adaptive;
- they can change their behaviour through the *feedback* process [25];
- they resist quantitative modelling [26].

Education has been classified as such a social system [5, 27] and therefore the various associated activities, like the curriculum development, can be studied through the relevant systemic conceptual tools. Such a generic tool is Systems Methodology, being one of the three domains of Systems Inquiry [4], which includes the methods, strategies, models and techniques for studying complex systems [5]. The other two domains of Systems Inquiry are:

- Systems Theory that investigates in an interdisciplinary manner the principles and models of abstract phenomena, independently of their nature or scale of existence [28];
- Systems Philosophy that concerns the systemic view of the world and the application of systems thinking in coping with theoretical and real-world problems.

Systems Methodology provides the method of *cognitive maps* [29] for modelling social environments, like an educational organisation. Such a systemic modeling technique will be presented in the following section.

3.1. Systemic Modelling

The Organizational Method for Analyzing Systems (OMAS-III) is a systemic modeling technique [30, 31, 32, 33] that evolved from earlier software engineering and analysis techniques of Information Systems [34, 35]. It is compatible:

- to the *General Systems Model* [36], which describes any system according to the *input-process-output-feedback* quadruple terms;
- to similar models of human communication [37, 38] for improving its communicational abilities compared to the previous techniques and therefore its understandability.

According to OMAS-III (the 3rd improved version of the initial technique), the definition of a system consists of six elements that are determined by answering the seven *journalists questions*, in a similar manner to the Inquiry Approach model (see: *2.4. The Inquiry Approach model*):

(i) *Why* determines the *purpose* of the existence of a system.
(ii) *What* determines the *output* of a system that includes the produced outcomes and the *feedback* operation.
(iii) *Which* determines the *input* of a system that includes data, material and human resources.
(iv) *How* determines the *rules* for the functions of a system that include legislation, regulations, restrictions and conditions.
(v) *Who* determines the *monitor* of the system that interferes in a regulatory and managerial manner.
(vi) *Where* determines the spatial aspects of the *structure* of a system that is the last of its elements to be mentioned.
(vii) *When* determines the temporal aspects of the *structure* of a system.

The relations between the above elements describe the entire operation of the studied system, its boundaries with the rest of the world and the energy flow between its elements [27]. The depiction of these relationships formulates a cognitive map that facilitates Systems Inquiry.

3.2. Modelling a Curriculum

In the discipline of Education and training, OMAS-III has been proposed and/or applied for developing curricula in career guidance extracurricular projects within school-context [1], in martial arts training [39], in postgraduate courses of various topics [40, 41], in language teaching [42], in teachers training [43] and other schooling activities (to be published soon). Herein it is proposed as a general systemic model for curriculum development, according to the guidelines of the previous section (see: *3.1. Systemic Modeling*) and in relation to the characteristics of the previously mentioned models (see: *2. Related framework*).

3.2.1. Why & Purpose

The qualitative and quantitative features of education are socially dictated in democratic societies. This reality is exemplified in the Greek society, where although the structure and the needs of the economy require more of a flexible secondary and post-secondary vocational education [44, 45], the social context is in favour of an inflated tertiary education [46]. Nevertheless, the present element (3.1. i) may cope with the criticism of Smith [16] and Cornbleth [19] about the absence of a consideration for the social context of curriculum development (see: *2.7. The modeling of Smith*). Thus, the social expectations that are associated with the development of a curriculum, e.g. like the personal development of students, can be met in this element, which is a common ground to all the models of curriculum development (see: *2. Related framework*).

3.2.2. What & Output

The outcome of the development process (3.1. ii) is the curriculum that according to Stenhouse [47]: "… is an attempt to communicate the essential principles and features of an educational proposal in such a form that it is open to critical scrutiny and capable of effective translation into practice". Herein, it is essentially perceived as a document of guidelines that includes: the didactic objectives, which are heavily influenced by the purpose of the system (see: *3.2.1. Why & Purpose*); the syllabi of courses; the suggested bibliography; the teaching methodology; the required infrastructure (type of labs, ICT devices, etc.); the proposed timeline and the assessment practices (feedback). The feedback operation refers also to quality assurance methods, like the Total Quality Management, where the assessment focuses on the process instead of the outcomes [48]. Systemic modeling can facilitate quality assurance by determining the various elements of the process and evaluate their contribution to the entire system [1].

3.2.3. Which & Input

The input element of the development process (3.1. iii) consists of all the available resources. Namely, the syllabi of courses and the relevant bibliography, the available infrastructure that may differ from the required one (see: *3.2.2. What & Output*), the teaching material (books, manuals, notes, handouts, questionnaires, exercises, activities, etc.), a probable cost estimation and other financial considerations. The human resources of this element consists of the students, along with their related features that include age, social and cognitive background, personal skills and other abilities (or disabilities), formal education information, expectations, participating goals and motivation. This last feature is very important because by keeping the students highly motivated, the problem of drop-out may be significantly reduced [49].

3.2.4. How & Rules

Regarding the rules and conditions of the development process (3.1. iv) that are socially influenced (see: *3.2.1. Why & Purpose*), they mainly include the relevant national legislation, the regulations of the educational organization, the local social conditions and the teaching methodologies (2.5. i). The choices made in the last topic dictate the nature of the teaching-and-learning practice. For example, there is a growing demand for the development of the social skills of graduates in a vocational context, which are usually acquired through self-learning outside the school environment [50]. There is also the learning practice of apprenticeship that is frequently conducted in a mixed manner, both inside or outside an educational organization. These learning practices require specific methods that are more suitable for the teaching task in hand, like the *Collaborative*, the *Problem-Based* and the *Blended* learning [1, 51]. Consequently, the outcome of such a choice will be a more Experiential curriculum (see: *2. Related framework*), since the model of curriculum as a syllabus (2.7. i) along with its associated criticism of not being suitable for informal education [3, 16, 20, 21] will not be applicable in this case.

3.2.5. Who & Monitor

Quoting Smith [16]: "… there is the 'problem' of teachers. The major weakness and, indeed, strength of the process model is that it rests upon the quality of teachers. If they are not up to much then there is no safety net in the form of prescribed curriculum materials". The validity of this statement goes beyond the process model of curriculum (2.7. iii). The quality of the teachers is a crucial element to be directly considered (3.1. v). Their ability to adequately perform their task is a major concern of teachers' training [1, 2, 7, 43], in order to ensure a necessary minimum quality of them [53], especially when innovations in didactics must be introduced and/or supervised [1, 52]. Nevertheless, most contemporary models of curriculum development (see: *2. Related framework*) ignore this element, maybe because it is taken for granted, although it is indirectly considered in the cases of collaboration between teachers from different disciplines (2.2. iv) and of the consulted groups for curriculum development and/or revision (2.4. viii).

3.2.6. Where/When & Structure

Finally, all the previous elements are utilized for the planning of the didactic activities (2.5. iv). Once having the outcome (see: *3.2.2. What & Output*) broken down to main activities in a backward design (see: *2.2. The model of Greer* and 2.5. iii), this process can be recursively applied to each activity for defining the implementation details, from start to finish ("Curriculum"). The issues of timeline (2.2. ii) and of the proper utilization of the available infrastructure (see: *3.2.3. Which & Input*) will be dealt with in this element (3.1. vi and 3.1. vii).

3.3. Comparison & Commentary

A comparison between the elements of OMAS-III for developing a curriculum (see sub-sections 3.2.1-3.2.6) to the key-points of the previously mentioned models (see: *2. Related framework*) is presented in Table 1. Every row of Table 1 (except the head-one) refers to the key-points of the associated model (in the first column) according to the equivalent element of OMAS-III that roughly corresponds to (in the head row).

Table 1. *A comparison of previous models to OMAS-III.*

Models	Why (3.2.1)	What (3.2.2)	Which (3.2.3)	How (3.2.4)	Who (3.2.5)	Structure (3.2.6)
Taba 2.1	i	ii, iii, viii	iv	vi	-	v, vii
Greer 2.2	i	v	iii	iv	-	ii
OBM 2.3	-	i, iv	ii	iii	-	ii
IAM 2.4	i	ii, iv, vi	v	iii	viii	-
ICDM 2.5	i	ii, iii	iv	i	-	-
UID 2.6	-	-	-	i-vi	-	vii
Smith 2.7	iv	ii	i	-	-	iii

The comparison in Table 1 reveals that most existing models don't fulfill a couple of systemic prerequisites (elements) each. The closest model to this systemic perception of curriculum development is the Inquiry Approach model (IAM *2.4*), because of its compatibility to the Systems Inquiry [4] approach (see also: *3.1. Systemic Modelling*). Nevertheless, it is argued herein that OMAS-III (along with the systemic approach, in general) is not necessarily competitive to the rest of the existing models. It can be rather viewed as supplementary, namely as a generic methodology that facilitates the usage of whatever best each of the existing models has to offer, in a unified working framework.

3.4. An Application Example

The application of the afore-mentioned systemic modeling (see: *3.2. Modeling a curriculum*) will be now demonstrated, in a rather simplified example. The objective was to develop a curriculum for a postgraduate programme (MSc) in Linguistic Computing [41]. The presented curriculum was designed as a proposed revision for the equivalent interdisciplinary MSc "Technoglossia", which was offered until 2013 jointly by the Department of Linguistics of the National & Kapodistrian University of Athens and the School of Electrical & Computer Engineering of the National Technical University of Athens [54].

3.4.1. Purpose & Output

Linguistic Computing (alias: Natural Language Processing; Computational Linguistics; Linguistic or Natural Language Engineering) is a branch of Artificial Intelligence [55] that, by combining linguistics and computer science, develops software research and applications, from plain digital dictionaries to communication with robots in natural language. The purpose of the relevant postgraduate studies (see: *3.2.1. Why & Purpose*) is to train linguistic software engineers that will be capable of developing applications in this state-of-the art discipline. The output of the systemic modeling (see: *3.2.2. What & Output*) is the required curriculum for the desired purpose.

3.4.2. Rules & Monitor

The main conditions of conducting a postgraduate programme (see: *3.2.4. How & Rules*) are dictated by national legislation [56, 57, 58]. Its usual duration is determined to three or four semesters that may include one semester for dissertation and apprenticeship. The universities' practice, through their internal regulations, is indeed to devote the last semester of studies to the dissertation and apprenticeship. The former gives to the graduate the opportunity to develop a full scale application, while the latter implements the notion of work-based learning.

In some occasions, a university may not have the proper academic staff to teach certain courses (see: *3.2.5. Who & Monitor*). In such a case, visiting professors or external experts are eligible to undertake this task.

3.4.3. Input & Structure

The candidate students of the postgraduate programme (see: *3.2.3. Which & Input*) are either linguists, which must be initially trained in computer science, or computer engineers that have to be similarly trained in linguistics. This particular teaching necessity increases the number of the required courses, thus leading to a four-semester curriculum (see: *3.4.2. Rules & Monitor*) that consists of:

- the introductory semester, different for each discipline, namely courses for linguists (computer science) and courses for computer engineers (linguistics);
- the core semester, common from now-on to both disciplines, with elementary courses of linguistic computing;
- the advanced semester, with courses for various topics of linguistic computing;
- the application semester, with the dissertation and apprenticeship.

The development of this curriculum followed the principle of *backward design*. Its structure (see: *3.2.6. Where/When & Structure*) will be presented in Table 2, regarding the courses of the first three semesters.

Table 2. *The structure of the curriculum.*

1st Introductory Semester	
for Linguists (6 compulsory courses)	**for Computer Engineers (6 compulsory courses)**
Introduction to Computing	Introduction to Linguistics
Computer Programming	Phonetics & Phonology
Databases	Morphology & Lexicography
Human-Computer Interaction	Syntax
Logic Programming	Semantics
Software Engineering	Pragmatics
2nd Core Semester (6 compulsory courses)	**3rd Advanced Semester (5 free selections from 8 courses)**
Grammar Formalisms	Machine Translation
Computational Phonetics & Phonology	Information Retrieval
Computational Morphology & Lexicography	Dialogue Systems & Interfaces
Parsing Algorithms	Text & Corpora Linguistics
Computational Semantics & Pragmatics	Machine Learning
Quantitative Linguistics	Artificial Intelligence
	Educational Software
	Advanced Contemporary Topics

To summarize, the curriculum comprises 24 taught courses, in total. Before the 4th semester commences, every student will have attended 17 courses. Each course is taught for four hours per week in average, including a theoretical (lectures) and a practical (assignments, laboratory) part, with the ratio of hours between the parts at the discretion of the teacher. The three initial courses of the first two semesters (Introduction to Computing; Introduction to Linguistics; Grammar Formalisms) are solely taught for the first two weeks of each associated semester, because they are a prerequisite for the rest of the courses of the relevant semester. This is an old yet reliable teaching practice, namely to conduct a single intensive introductory course at the beginning of a semester (e.g., see: [59]).

Regarding the crucial issue of how to select the content of the particular curriculum, the initial criterion is the postgraduates' *vocational profile* (see: *3.4.1. Purpose & Output)*. Such a profile was formulated by conducting a survey that investigates the requirements of the relevant labour-market [60], namely what a linguistic engineer will be asked to do. Major international organizations, like the Organization of Economic Cooperation and Development (OECD) and the World Economic Forum (WEF), are interested in improving the corresponding of the skills of professionals to the requirements of the labour-market, in general [61, 62]. Thus, it is more than obvious that a qualified linguistic engineer must be capable of meeting most of the relevant requirements, as they conventionally appear in job announcements. The interested employers could be private enterprises, academic and research institutions. By following the principle of *backward design*, the required applications were grouped into major topics that directly correspond to the courses of the 3rd Advanced Semester (Table 2). Then, the prerequisite courses of the 2nd Core

Semester were defined, in order to cover all the fields of language analysis that simultaneously comprise the necessary knowledge background for the next semester. Finally, considering the different initial background of the admitted postgraduate students (either linguists or computer engineers), the 1st Introductory Semester was structured accordingly in two separate directions of study.

To include the 4th application semester in the curriculum ensures the acquisition of two major professional skills. First, that the ability of the qualified linguistic engineers to apply their knowledge is attested through the apprenticeship. Second, that their ability to confront future trends is developed through the dissertation, which usually concerns a contemporary research topic.

4. Conclusions

A curriculum can be developed along the concepts and guidelines of Systems Inquiry and especially Systems Methodology. The development process can be modelled according to the systemic technique of OMAS-III that can be applied in order to determine all the major elements of structuring the curriculum in terms of purpose, results, regulations, educators, target group of students, required information and syllabi. Having all of them related, the designing process is implemented in a holistic manner that can cope with the deficiencies of other methods in defining important factors of curriculum development (Table 1) that could be easily neglected. The most notable such factor is the ability of educators to implement the developed curriculum. In this respect, the systemic approach can be applied as a generic methodology that may facilitate the usage of the key-points of other existing models, wherever appropriate, in a unified developing framework.

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