A Curriculum Design Approach by the Means of a General Morphological Analysis*

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Recibido: 11/10/2018 • Aceptado: 14/03/2020

https://doi.org/10.22395/rium.v19n37a3

Abstract

The context of conceiving, designing, implementing, and operating real-world systems and products, namely the CDIO initiative, is a framework for engineering education. It considers 12 standards, which are the reference for curriculum design and assessment. A good implementation of the CDIO standards can be considered as a multi-dimensional complex problem. In order to propose strategies for implementing the CDIO initiative in the Electronic Engineering curriculum at Universidad del Quindío, the General Morphological Analysis (GMA) was used. Some relevant dimensions of the curriculum and their values were contrasted in a cross-consistency assessment (CCA), where 8 dimensions were established, and a total of 34,560 combinations were obtained in the problem space. Through the CCA, the number of coherent combinations was significantly reduced. Finally, these combinations were analyzed to propose the corresponding strategies that are the input for the implementation of the CDIO curriculum in the Electronic Engineering program.

Keywords: curriculum design, engineering education, general morphological analysis (GMA), CDIO.

* This paper was founded by the research project "General Morphological Analysis (GMA) applied to the CDIO-Curriculum of the Electronics Engineering Program at the Universidad del Quindío"; it was started in 2018, ID 913 – Universidad del Quindío.

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Aproximación al diseño curricular mediante análisis morfológico general

Resumen

La iniciativa CDIO —esto es, concebir, diseñar, implementar y operar sistemas y productos del mundo real— es un marco para la educación en ingeniería que considera 12 estándares como referencia para el diseño y evaluación del currículo. Respecto del diseño curricular, una buena implementación de los estándares CDIO puede considerarse un problema complejo multidimensional. Con el objetivo de proponer estrategias para implementar la iniciativa CDIO en el currículo de Ingeniería Electrónica de la Universidad del Quindío, se usó el análisis morfológico general (GMA). Así, algunas dimensiones relevantes del currículo y sus valores se contrastaron en una evaluación de consistencia cruzada (CCA) dentro de la cual se establecieron 8 dimensiones, para un total de 34.560 combinaciones en el espacio de problema. Con lo anterior, el número de combinaciones coherentes se redujo de forma significativa. Finalmente, esas combinaciones se analizaron para proponer las estrategias como insumo para la implementación del currículo CDIO en Ingeniería Electrónica.

Palabras clave: desarrollo curricular, educación en ingeniería, Análisis Morfológico General (GMA), CDIO.

Aproximação ao desenho curricular mediante análise morfológica geral

Resumo

A iniciativa CDIO — isto é, conceber, desenhar, implementar e operar sistemas e produtos do mundo real — é um marco para a educação em Engenharia que considera 12 padrões como referência para o desenho e a avaliação do currículo. Com relação ao desenho curricular, uma boa implementação dos padrões CDIO pode ser considerada um problema complexo multidimensional. Com o objetivo de propor estratégias para implementar a iniciativa CDIO no currículo de Engenharia Eletrônica da Universidad del Quindío, utilizou-se da análise morfológica geral (GMA). Assim, algumas dimensões relevantes do currículo e seus valores foram contrastadas numa avaliação de consistência cruzada (CCA) dentro da qual se estabeleceram oito dimensões, para um total de 34.560 combinações no espaço de problema. Com isso, o número de combinações coerentes reduziu-se de forma significativa. Finalmente, essas combinações foram analisadas para propor as estratégias como insumo para a implementação do currículo CDIO em Engenharia Eletrônica.

Palavras-chave: desenvolvimento curricular, educação em Engenharia, Análise Morfológica Geral (GMA), CDIO.

INTRODUCTION

The implementation of the CDIO framework in an academic program faces several challenges. One of these is the curriculum design, since it involves a detailed analysis of the context in order to propose a design that satisfies the context requirements. To address this challenge, there is a recent interest to consider the curriculum design as a complex problem that can be aided by mathematical and computational tools [1-4]. In this paper, we use a tool called General Morphological Analysis (GMA) to deal with complex problems, aiming to perform a conceptual analysis about the implementation of a CDIO curriculum. This analysis is contextualized in the Electronic Engineering Program at Universidad del Quindío (Colombia).

A previous work was presented in the 13th International CDIO Conference at Calgary, Canada, titled "Conceptual Verification of CDIO Skills in the Electronic Engineering Curriculum at Universidad del Quindío" [3], using a different tool, the Formal Concept Analysis (FCA). In that work, we developed an attribute exploration using FCA for two different contexts: the design-implement projects, and the integration of the skill training across the courses in the curriculum.

In the CDIO framework, the curriculum is stated in the CDIO standard three (integrated curriculum) [5]. According to the CDIO guidelines, the curriculum design behaves as a complex problem as described below. The definition of a complex problem is given by Horst Rittel in [6]. Rittel and his collaborators established in the 1970s that a complex problem exists when different technical concepts and socio-political interests are involved. In the case of the curriculum design, this complexity appears due to the involved actors and interests:

- The students, and their expectations for training and future job opportunities.
- The specific disciplinary knowledge and skills in the training area, and the strategies for their effective teaching.
- The institution and program's purposes, which are stated in the professional outcomes.
- The government requirements to meet quality standards.
- The society needs for professionals to effectively solve the problems that arise in the search for a better lifestyle.

Horst Rittel called this kind of problems as "wicked" ones, opposed to the so-called "tame problems". Solving a wicked problem as if it were tamable constitutes an endless cycle of attempts to reach the solution. Some criteria to identify that the curriculum design is a wicked problem are the following [7]:

1. No definitive formulation of a complex problem. Since the curriculum is constantly evolving, we cannot establish something as "the definitive design". Instead, we must use tools to carry out an exhaustive inventory of all imaginable solutions in advance.
2. Wicked problems do not have stop rules. This corresponds to the question: how do we know that we have designed the best possible curriculum? In other words, neither we can state that we have reached the final solution, nor that it is completely correct. A curriculum design ends when, subjectively, all stakeholders involved in it agree that its structure satisfies all initial requirements and needs stated at beginning.
3. Solutions to wicked problems are not true or false, but better or worse. The solution depends strongly on the stakeholders. Since the curriculum design involves different actors, each actor perceives different solutions as better or worse.
4. There is not an immediate and definitive test for validating the solution to a wicked problem. After implementing a curriculum, the consequences are observed in a virtually unlimited period of time, *i. e.,* a curriculum may have completely undesirable repercussions that may exceed the expected or desirable benefits envisioned at the beginning.
5. Each solution to a wicked problem is a one-shot operation. Since curriculum designers have no opportunity to learn by trial and error during the design process, all the attempts count in a significant way. The implementation of a new curriculum has consequences, such as leaving traces in students' performance and their acquired skills. In addition, each attempt to reverse a decision, or to correct the unwanted consequences, raises another series of complex problems. These issues count from the point of view of the graduates.
6. Wicked problems do not have an enumerable (or feasible to describe) set of potential solutions, neither there is a well-described set of permissible operations that can be incorporated into the plan. In the case of a curriculum design, its implementation depends on the context and the disciplinary trends.
7. Each wicked problem is essentially unique, *i. e.,* it is not possible to establish categories for wicked problems. In the curriculum design, there is no solution principles that can be adapted to all contexts. It requires a process of analysis and synthesis to find out the solution type to be applied.
8. Each wicked problem can be considered as a symptom of another wicked problem. It is evident that the problem of curriculum design is immersed in the general problem of education, where a society demands competent professionals to satisfy specific needs.

9. The causes of a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of problem resolution. For this reason, curriculum design has become a research in progress, where different regulations and procedures have been developed to generate the best design. However, it also possible to propose several ways to refute the hypotheses on which the curriculum design is based on.

10. For wicked problems, the planner has no right to make mistakes. From the point of view of curriculum design, the planners are responsible for the consequences arising from the implementation of the curriculum. Whereas a hypothesis in the sciences can be refuted to find the truth, in the search for the solution of a wicked problem, the objective is not to find the truth, but to improve some environmental features. In the context of curriculum design, the environment is related to the quality of life for a given community, so that the social impact of a curriculum design is measured by how graduates contribute effectively for a better quality of life in their social context.

Among the available alternatives to address the solution of a wicked problem, we have chosen a systematic approach called General Morphological Analysis (GMA) [7]. This approach has the capability of generating a problem space, and possible solution spaces. Thus, through a process of analysis and synthesis of this solution space, it is possible to find alternative solutions, which are called morphotypes. To perform this analysis, it is necessary to use a software tool to support the entire GMA process [8]. To conduct the analysis in this paper, we designed a software tool using the LabView environment, and the information used to feed the GMA analysis (dimensions and values) is described in the next section.

1. STRATEGIES AND METHODS: CREATING A MORPHOLOGICAL FIELD FROM A CURRICULUM

1.1 The CDIO Initiative

The CDIO initiative is an association of more than 130 universities worldwide that have adopted a methodological model for engineering training. This model states that the newly graduated engineer must be able to conceive, design, implement, and operate products, systems, and processes in collaborative environments [9]. This training approach implies the development of disciplinary, personal, interpersonal, and professional skills that are expected for an engineer.

In 2004, the CDIO initiative adopted 12 standards to guide the principles of CDIO programs. These CDIO standards define the features that distinguish a CDIO program from traditional ones, serve as guidelines for curriculum design and evaluation of educational programs, generate benchmarks, and provide a framework for continuous improvement.

The twelve CDIO standards address the philosophy of the program (standard 1), development of the curriculum (standards 2, 3 and 4), design-build experiences and working spaces (standards 5 and 6), teaching and learning methods (standards 7 and 8), teacher development (standards 9 and 10), and evaluation (standards 11 and 12) [10]. In this article, we make a special emphasis on the elements that describe the curriculum structure and pedagogical practices for a CDIO program. These elements are stated mainly in the following standards [10]:

- Standard 2. Learning outcomes. According to the CDIO principles, the engineer training is emphasized in learning experiences with verifiable results, which involve constant planning of goals and generation of deliverables. This training implies the development of skills in four categories: disciplinary, personal, interpersonal, and professional (*i. e.* skills to conceive, design, implement and operate systems). These skills must be explicit in the courses' syllabus as intended learning outcomes (ILOs). CDIO provides a concise description of the desired skills in the CDIO syllabus [11].
- Standard 3. Integrated Curriculum. This includes the strategies for improving the personal and interpersonal skills of the student, as well as the acquisition of product, process, and system building skills (professional skills). In this sense, the disciplinary courses must be explicitly interconnected to support the development of the learning outcomes and skills.
- Standard 5. Design-Implement Experiences. This standard refers to the training of engineers who are able find solutions to problems in context from the conceptual design (conceive) to the methodological design (implement).
- Standard 7. Integrated Learning Experiences. The disciplinary training of engineers, based on learning experiences, involves factors of diversity, topic connections, and development of professional skills.
- Standard 8. Active Learning. This standard refers to the usage of pedagogical methodologies that engage students in manipulating, analyzing, applying, and evaluating ideas, rather than passive transmission of information. Thus, active learning provides a way to acquire disciplinary knowledge simultaneously with the development of personal, interpersonal, and professional skills.
- Standard 9. Enhancement of Faculty Competence. The implementation of the CDIO framework requires the professional experience of the faculty to be prioritized not only in research, but also in the industrial sector.

- Standard 11. Learning Assessment. In the context of an engineering training based on knowledge experiences, active methodologies, and skills development, it is necessary to consider a complete assessment system suited to these requirements.

1.2 GMA Methodology

The GMA methodology was proposed and developed by Fritz Zwicky at the California Institute of Technology (Caltech), as a strategy to solve complex problems [8]. This methodology has been applied to different fields, such as [8] engineering and product design, general design theory and architecture, futures studies and scenario development, technology foresight, and technological forecasting, among others. In [8], the curriculum design is also considered as a potential application of GMA. Hence, this paper explores the usage of GMA for the implementation of a CDIO curriculum in an Electronic Engineering program.

The GMA methodology starts by defining the dimensions or parameters for the given problem. If dimensions are defined within the same context, we are dealing with a simplex model; by contrast, in the multiplex model the dimensions belong to different contexts or frameworks.

Next, different values or alternative solutions are proposed for each dimension. The values within a given dimension must be mutually excluding, so that choosing a particular value in a dimension is the only feasible solution for the selected dimension. Finally, a cross-consistency matrix is constructed for the problem space. In this matrix, a particular matrix element is referred to the compatibility of the combination of two values from different dimensions. If the combination of these two values is convenient, the matrix element is marked with "_". On the other hand, if the combination is impossible or inconvenient, the matrix element is marked with an "x".

A feasible solution for the whole problem is such that choosing one value for each dimension produces a set of values that are mutually convenient according to the cross-consistency matrix. This solution is called "solution space" or "morphotype", according to the GMA terminology. Besides, by fixing the value in a particular dimension, it is possible to analyze alternative solutions (or solution spaces) in the remaining dimensions based on the convenience of these combinations, according to the cross-consistency matrix.

The higher the number of dimensions, the higher the complexity of the analysis. Therefore, it is necessary to use a software tool to aid the analysis of these alternative solutions: This is one of the four necessary requirements proposed by Tom Ritchey for developing the GMA [7]. The software tool must allow us to find different solution spaces across dimensions. If several dimensions are present, this process may be complicated, or even impossible, without a dedicated software tool. To develop a proper morphological analysis, a LabVIEW-based software [12] that uses the morphological field and the cross-consistency matrix [13] was elaborated. This allowed us to find and select different morphotypes, or configuration fields, which are solutions when only one value for each dimension is active.

1.3 GMA Applied to Curriculum Design

For the purposes of this work, we use the rubrics stated in the CDIO standards 2, 3, 7, 8, 9, and 11 [5] to propose the following eight dimensions in our GMA model:

A. Type of curricular structure.

B. Strategies to train professional skills (*i. e.* personal, professional, interpersonal, and CDIO skills) in the students.

C. Strategies to integrate professional skills in the study plan (macro viewpoint).

D. Development of professional skills in the faculty.

E. Strategies to enhance faculty skills for integrated learning experiences, learning methods, and evaluation strategies.

F. Strategies to evidence the alignment of program ILOs [14] with area-specific ILOs.

G. Strategies for assessing professional skills development in students.

H. Strategies to evidence how are professional skills integrated in the courses.

The organizing principle for the proposed analysis is to first consider the dimension A, since that one is important to start a curriculum design process [5]. The support for training, assessment, and integration of professional skills in the curriculum design is included in the remaining dimensions (B, C, D, E, F, G, H), attending the principle of constructive alignment [14].

Based on the previous principles, the rubrics for each CDIO standard, and the theoretical foundation given in [3, 5, 14], an expert group proposed different solution alternatives for each dimension. This group is comprised of the people in charge of the curriculum design: Professors with more than ten years of experience in education for engineering and advanced knowledge in the CDIO approach. This group obtained solution alternatives that correspond to the set of values used to build the problem space, and the cross-consistency matrix. Since the values for a given dimension must be mutually exclusive according to the GMA methodology, in some dimensions, each proposed solution (or value) corresponds to the primary approach that should be addressed to fully satisfy the given dimension. For example, as shown below, for the dimension B (strategies to train professional skills in the students), some values (B2-teamwork and collaborative activities, B3-internships, and B4-classroom scenarios) could be complimentary solutions for this dimension, however, considering that only one value is enough to address the dimension. In other words, selecting only one value in any given dimension leads us to find a complete solution using the minimum amount of resources. The same kind of approach was conducted for all dimensions, were the expert group agreed to find values mutually exclusive or fully satisfying a given dimension. For the cross-consistency matrix design, the expert group analyzed the convenience and inconvenience for two values belonging to two different dimensions. Disagreements on the selection procedure by the expert group were solved by arguing on each viewpoint, and searching for complimentary information.

We propose the following values for each dimension:

- Dimension A
  - A1: Strictly disciplinary curriculum.
  - A2: Integrated curriculum.
  - A3: Problem-based curriculum.
  - A4: Project-based curriculum.
- Dimension B
  - B1: Integration of the high-order skills of the CDIO syllabus with the ILOs and the specific activities.
  - B2: Teamwork and collaborative activities that demand autonomous thinking for professional skills development.
  - B3: Implementation of internships in industrial environments that stimulate the development of professional skills in context.
  - B4: Classroom scenarios for the simulation of the issues commonly experienced in the industry or during the professional practice.
- Dimension C
  - C1: Constructive alignment between skills and the program’s outcomes, which is reflected in the syllabus of the courses.

- C2: Formal concept analysis that determine the integration level of skills in the curriculum.
- C3: Curricular and co-curricular spaces for the development of design-implementation experiences throughout the study plan, encouraging the acquisition of professional skills supported by disciplinary knowledge.

- Dimension D
  - D1: Workshops oriented to the training of the faculty in professional skills (these can be led by an expert).
  - D2: Enhancement of professional skills in the faculty by means of business practices or internships.
  - D3: Academic spaces for the development of design-implementation experiences throughout the curriculum, that encourage the acquisition of professional skills supported by disciplinary knowledge.
- Dimension E
  - E1: Workshops focused on, firstly, training the faculty in integrated learning experiences such as case studies, role games, or active learning, and secondly, on training it in how to align ILOs, activities, and evaluation. These workshops can be led by an expert.
  - E2: Policies and administrative support for professors' participation in CDIO conferences, workshops, or meetings on active learning and assessment. This also calls for them to share their experiences with the whole faculty.
  - E3: Sharing classroom experiences by professors that implement strategies for integrated learning, active learning, and aligned assessment, contrasting them with the skills stated in the syllabus.
- Dimension F
  - F1: Development of mind maps that relate each course's learning outcomes with program and area-specific ones.
  - F2: Verification through a dynamic matrix that demonstrates how each skill is introduced, taught, and applied throughout the study plan.
  - F3: Report on how the program's learning outcomes are reflected in the activities developed for each course. This report is shared with the faculty.
  - F4: Design-implementation projects associated with a particular course. The student performance is recorded during this project, according to the topics for a given depth level.

- Dimension G
    - G1: Establishing a profile with descriptors of student behavior regarding the topic in development. Associating descriptors with the expected performance levels, and developing an observation process based on rubrics applied in the classroom.
    - G2: Conducting written evaluations in which students are asked to self-assess their performance level, associated with a specific activity.
    - G3: Conducting surveys to inquire about the perception of the required level in the development of the topic.
    - G4: Formulating course projects strictly associated with the disciplinary knowledge, and observing performance results during the project.
- Dimension H
    - H1: Syllabus of each course with the description of the activities aimed at developing the proposed skills.
    - H2: Multimedia records of the classroom activities that develop the chosen skills.
    - H3: Log for the classroom activities addressing the topics related to the professional skills.
    - H4: Report on classroom experiences (of pedagogical and didactic types) for discussion with the faculty.
    - H5: Presentation to stakeholders of the products made from the design-implementation experiences in the classroom.

Since our previous analysis shows that all dimensions belong to the same context, the proposed model for the curriculum analysis is a *simplex model* [15]. It is an 8-dimensional space (Table *1*) which contains 4 x 4 x 3 x 3 x 3 x 4 x 4 x 5 = 34560 distinct formal configurations or morphotypes. To ease the analysis of this huge amount of morphotypes, only the morphotypes that are coherent with the cross-consistency matrix were considered, as described in the next section.

Table 1. Proposed 8-Dimensional Morphological Field

A	B	C	D	E	F	G	H
A1	*B1*	*C1*	*D1*	*E1*	*F1*	G1	H1
A2	B2	C2	D2	E2	F2	G2	H2
A3	B3	C3	D3	E3	F3	G3	H3
A4	B4				F4	G4	H4
							H5

Source: Prepared by the authors.

2. RESULTS AND DISCUSSION

A Cross-Consistency Assessment (CCA) [16] was performed on a cross-consistency matrix (see Table *2*) by checking the connective relationship and constraints between the dimensions. This assessment process was carried out by a team with experience on designing activities to develop skills in students and the faculty.

Table 2. Cross-Consistency Matrix for the Morphological Field in Table 1. X: It is not Possible or Inappropriate. _: It is Possible and Fully Appropriate/Optimal

1		A				B				C			D			E			F				G			
		2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	4	1	2	3	4	
B	1	X	_	_	_																					
	2	X	_	_	_																					
	3	X	_	X	_																					
	4	X	_	_	_																					
C	1	X	_	_	X	_	_	_	_																	
	2	_	_	_	_	_	X	X	X																	
	3	X	_	_	_	_	_	_	_																	
D	1	X	_	_	_	_	_	X	_	_	X	X														
	2	X	_	_	_	_	_	X	_	_	X	X														
	3	X	_	_	_	_	_	X	_	_	X	X														
E	1	X	_	_	_	_	_	X	_	_	X	X	_	X	_											
	2	X	_	_	_	_	_	X	X	_	X	X	_	_	_											
	3	X	_	_	_	_	_	X	_	_	_	X	_	X	X											
F	1	X	_	_	X	_	X	X	X	_	_	_	X	_	_	_	X	X								
	2	X	_	_	_	_	X	_	X	_	_	X	_	X	X	X	X	_								
	3	X	_	_	_	_	_	X	_	_	X	X	_	X	X	_	_	_								
	4	_	_	_	_	_	_	_	_	_	X	_	X	X	X	_	X	_								
G	1	X	_	_	_	_	X	_	_	_	_	_	_	_	_	_	_	X	X	X	X	_				
	2	_	_	_	_	X	_	X	_	X	X	_	X	X	X	_	X	_	X	X	_	_				
	3	_	_	_	_	_	_	_	_	X	X	X	X	X	X	_	X	_	X	X	_	_				
	4	_	_	_	_	_	_	X	_	_	X	_	X	X	X	_	X	_	X	X	_	X				
H	1	X	_	_	_	_	_	X	_	_	_	X	_	X	_	_	_	X	_	_	_	X	_	_	_	X
	2	_	_	_	_	_	_	X	_	X	X	X	_	X	_	_	_	_	X	X	_	_	_	_	_	X
	3	X	_	_	_	_	_	X	_	X	X	_	_	X	_	_	_	_	X	X	_	_	_	_	_	X
	4	_	_	_	_	_	X	X	_	_	X	_	_	X	_	_	_	_	X	X	_	_	_	_	_	_
	5	_	_	_	_	X	_	X	_	_	X	_	_	X	_	_	_	_	X	X	_	_	_	_	_	_

Source: Prepared by the authors.

The cross-consistency matrix was analyzed with the simulation software, finding that there is not a complete morphotype, *i. e.* we cannot find a solution that considers at least one value for each dimension. In fact, three (3) dimensions, D, F, and G, are mutually incompatible. Hence, complete morphotypes can be found in the remaining seven (7) dimensions by eliminating one of these three dimensions.

The incompatibility of these three dimensions must be considered carefully, either by reviewing the values of each dimension or by reviewing the values of the cross-consistency matrix. Considering that these three dimensions show incompatibility problems among them, we decided to find the morphotypes by using only the remaining dimensions when one of them is eliminated.

When the dimension D is eliminated, the morphological field can be reduced up to 22 morphotypes, which is a reduction of 99.80 %. If the parameter F is taken out, the solution space can be reduced to 28 morphotypes (99.75 %); and when the parameter G is eliminated, the solution can be reduced to 32 formal configurations (99.72 %). According to these results, an important reduction of the problem space is achieved. However, the values of the dimensions D, F, and G should be reviewed to avoid possible overlaps between the involved strategies. The cross-consistency matrix could be also reviewed. This review is proposed as a further work.

It was found that some values of the dimensions appear in three morphotype groups, or only two in the case of the deleted dimensions. This condition shows that these values have relevance in the curriculum's configuration. Table *3* presents the relevant values that were found for each dimension.

Table 3 shows some dimensions with only one relevant value. This result suggests that it could be the best option for the curriculum implementation. The dimensions and the associated values are C1, E1, F3, G1, and H4. In the other dimensions, two values are relevant: A2, A3, B1, B4, D1, and D3.

Table 3. Dimensions and Relevant Values

Dimension	Relevant values
A	A2, A3
B	B1, B4
C	C1
D	D1, D3
E	E1
F	F3
G	G1
H	H4

Source: Prepared by the authors.

The election of only relevant values for each dimension may help to reduce the number of options for curriculum implementation, and the searching for better solutions. In addition, the values that were not considered relevant according to this methodology imply that they do not constitute an effective opportunity for the design of a CDIO curriculum using the lowest amount of resources and strategies.

Taking into account the dimensions with incompatibilities, D, F, and G, only the first one has two values, but only D1 is compatible with the F3 and G1 values. Therefore, D3 can be discarded, and the solution space can be reduced. In the case of F3 and G1, they are incompatible according to the cross-consistency matrix. Therefore, other values must be considered to reformulate these dimensions.

According to this analysis, the kind of curricular structure, dimension A, has only two relevant values: Integrated curriculum, and problem-based curriculum. Among these values, the "strictly-disciplinary curriculum" option can be discarded because, according to the software, dimensions B, D, and E appear without values when A1 is selected. Besides, the other value of the dimension A, project-based curriculum, do not appear at any morphotype, even when dimensions D, F, or G are eliminated. This result suggests that this curriculum type is not a good option, even though it seemed promising when A4 was selected in the software. It should be noted that an integrated and a problem-based curriculum allow the integration of professional skill development.

3. CONCLUSIONS

In this paper, we addressed the curriculum design as a wicked problem, and analyzed different dimensions of this problem by using the general morphological analysis framework. As a work-in-progress, the results of this analysis are useful to find, and then select, the appropriate strategies to design and implement a CDIO curriculum in our engineering program. Our confidence in the results is supported by the relevance of the GMA method for design theories, strategic management, and scenario development. So, we evaluated different curriculum approaches to determine which one is suitable for the implementation of a CDIO program. From this evaluation, we concluded that an integrated (value A2) and a problem-based curricula (value A3) are the most convenient ones. Furthermore, from the morphotypes viewpoint, neither of the solution alternatives satisfies the full coverage of the whole problem dimensions.

However, three of these dimensions were identified as critical in the problem solution, since taking out at least one of them allows to obtain a problem solution covering the full scope of dimensions. These are D (development of professional skills in the faculty), F (strategies to evidence the alignment of program ILOs with specific-areas ILOs), and G (strategies to assess the development of professional skills in the students). Finally, the developed software tool allows us to reduce the problem space, and to seek out proper solutions for curriculum design problem. As future research, we propose to adjust the values for each dimension: These can be matched to the needs of a particular program.

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