A proposal for graphically representing curriculum designs by using pre-conceptual schemas in computing-related undergraduate programs

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Abstract—Curriculum recommendations for computing-related undergraduate programs are approached from the ACM, AIS, and IEEE Computer Society. In educational settings, each undergraduate program makes its own adaptations to the curriculum in accordance with its profiles. Curriculum designs that were the result of such adaptations have graphical representations of educational aspects in a non-standardized way. Facing such a situation, an alternative to curriculum design based on pre-conceptual schemas in computing-related undergraduate programs is proposed. The benefits of curriculum design by using pre-conceptual schemas are applicability to any context, graphical unification of all educational aspects to be considered, and usage of tightly-coupled semantics.

Keywords—pre-conceptual; schemas; computing; undergraduate; programs; curriculum; design.


Una propuesta para representar gráficamente los diseños curriculares utilizando esquemas preconceptuales en programas de pregrado relacionados con la computación

Resumen—Las recomendaciones curriculares para los programas de pregrado relacionados con la computación se abordan desde la ACM, AIS y la IEEE Computer Society. En entornos educativos, cada programa de pregrado realiza sus propias adaptaciones al currículo de acuerdo con sus perfiles. Los diseños curriculares que fueron el resultado de tales adaptaciones tienen representaciones gráficas de aspectos educativos de una manera no estandarizada. Ante tal situación, se propone una alternativa al diseño curricular basado en esquemas preconceptuales en programas de pregrado relacionados con la computación. Los beneficios del diseño curricular mediante el uso de esquemas preconceptuales son la aplicabilidad a cualquier contexto, la unificación gráfica de todos los aspectos educativos a considerar y el uso de semánticas estrechamente acopladas.

Palabras Clave—preconceptual; esquemas; computación; pregrado; programas; currículo; diseño.

1 Introduction

Curriculum design is an activity in constant evolution; this nature of continuous change in curriculum aspects has promoted strategies for the standardization of contents. This is the case of the people of the ACM, AIS, and IEEE Computer Society, who have formulated curriculum recommendations for computing-related undergraduate programs, to create a common ground regarding contents [1].

The existence of recommendations that allow for standardizing contents is a great support for curriculum design issues; nonetheless, each undergraduate program is free to follow them or not. In this vein, curriculum designers in each undergraduate program make their own adaptations of what they believe the curriculum should have, considering the profiles in the educational scenario.

Commonly, curriculum designs of undergraduate programs involve the following educational aspects: educational aims, teaching-learning strategies, scope and sequence, syllabi and syllabus design, content outline, standards, educational resources, assessment strategies and planned experiences, among others [2]. Such educational aspects are graphically represented in a non-standardized way. In this study are found, structural, procedural, and methodological views in a series of non-standardized representations.

Dealing with the current situation in the background, the use of pre-conceptual schemas for curriculum design in computing-related undergraduate programs is stated. Curriculum designers can establish just one common graphical way that allows them to represent every single educational aspect within the curriculum design process by using pre-conceptual schemas.

Pre-conceptual schemas grant benefits to the curriculum design. Given their general-purpose nature, pre-conceptual schemas can be applied in any context. In the specific field of education, their tightly-coupled semantics allows for: representing a unified structure for syllabi, using requirements and sequentially of contents, designing teaching-learning strategies, modeling assessment, and using educational resources.

This paper has 6 sections. The first one has an explanation of the study context. The second one has a description of the findings in the field of knowledge related to curriculum design, including the problem statement. The third one contains the formulation of the proposed solution by using pre-conceptual schemas. The fourth one has a description of the benefits of such a proposed solution. Conclusions are presented in the fifth section. Lastly, a series of future works from the present study is described in the last section.

2 Context

For the ACM, AIS, and IEEE Computer Society, disciplines are the largest epistemological divisions in terms of knowledge associated with computing. Each of
them has a purpose; the way these five disciplines were defined is presented below:

Computer Engineering is the discipline of designing and building computer-based systems. It involves the study of hardware, software, communications, and their interactions. Computer Science is the discipline related to the theoretical and algorithmic foundations of the state-of-the-art developments in computing-based systems. Information Systems is the discipline focused on integrating information technology solutions and business. Information Technology is the discipline for preparing professionals to meet the needs of computer technology in businesses, government, and other types of organizations. Software Engineering is the discipline focused on the development and maintenance of software systems with high levels of quality [1]. General contents have been studied through the elaboration of descriptors for main topics. As a matter of fact, the main topics proposed by the ACM, AIS and IEEE Computer Society have a great correspondence with the results of the research based on automated curriculum analysis [3].

In such a context, advances in computing have forced the permanent redesign of the curriculum in undergraduate programs. Bodies of knowledge establish a series of guidelines to be implemented for each curriculum designer [4]; nonetheless, each curriculum designer develops the job in isolation. The following is a study on curriculum designs for computing-related undergraduate programs, so it is possible to appreciate the different ways for graphical representations of educational aspects.

3 Background and problem

At the time of designing the curriculum, each undergraduate program is free to adapt its own methodology of work. Given such freedom, the educational aspects are considered in several ways; in fact, some of them are not entirely considered or there is a major focus only in a part of them. Some curriculum designs deal with the contents only, others work with contents and teaching-learning strategies. This study has performed a search of different curriculum designs worldwide, resulting in a series of 15 graphical representations to be considered.

The first sample of curriculum design is proposed by William Burkett, who proposes an 8-step curriculum development template, and the general structure of courses with prerequisites by using blocks in sequence [5]. For Burkett, curriculum design is based on two educational aspects: the methodology of construction and the sequential representation of the courses in the program. Such a proposal is shown in Fig. 1.

![8 Step Curriculum Development Template](image)

**Figure 1. The methodology of construction and the sequential representation of the courses.**

Source: [5]

The second sample of the graphical representation is based on a graph chart with connected nodes and tabular descriptions [6]. The graphical representation of the sequential courses is proposed; in that case, just one educational aspect was considered, the graph is shown in Fig. 2.

A synergistic interaction model is proposed by Br. Desai and Dr.
von der Embse. According to the authors, the educational institution interacts with business organizations to define the main topics to be considered into the curriculum [7]. The authors use Venn’s diagrams for their purpose, as can be seen in Fig. 3. Such a proposal deals with just one educational aspect related to contents, considering their intersections in the fields of knowledge.

The following work contemplates several ways of graphically representing different educational aspects, as shown in Fig. 6.

Another proposal is a layer-based architecture with representation in blocks [8]. Such a proposal was raised for a Chinese university and was used one educational aspect related with contents in the schema of courses, as shown in Fig. 4.

Focusing on content, another way of representing a curriculum is based on a flow-path diagram, in which can be seen how a student advances in an education process through the development of a path [9]. Fig. 5 shows the usage of one educational aspect related to contents including course sequentially.

The authors use a semiformal UML notation (activity diagrams) to graphically represent their curriculum designs [10]. Despite the usage of several diagrams, just one educational aspect was considered, the contents involving sequential paths.

Another way for representing contents in curriculum design is using areas in a matrix of a representative collection of technologies and innovation stages [11]. This way to design a curriculum helps the formulation of courses for the program. Fig. 7 shows how to distribute the main topics into the matrix.

The curriculum design depicted in Fig. 7 uses two educational aspects: the definition of the course structure and the educational purposes. In this manner, the authors integrate
the matrix contents and educational purposes as the basis for the formulation of the academic courses.

The common aspect of curriculum design that has been considered so far: the course structure; however, curriculum design is more than an activity to create a course structure [12]. In curriculum design, several educational aspects such as pedagogical models, teaching-learning strategies, assessment activities, and others, should be considered in addition to the specification of just a course structure. A block diagram can be useful regarding a course structure. In Cleveland State University, a curriculum for the Information Systems program was proposed by using such a diagram [13]. In such a proposal, just one educational aspect was used, as shown in Fig. 8.

Figure 6. Content and sequential representation. Source: [10]

Particular conceptions about how to design a curriculum in a computing-related undergraduate program depend on the designers. Sometimes the methodology itself is relevant at the moment of designing. This is the case of a proposal from the University of Northern Colorado, which graphical representations point towards establishing design criteria as perspectives in education [14]. In such a work, the authors emphasize the importance of defining the methodology for designing a curriculum in the first instance, rather than directly entering the curriculum design itself.

The authors create clouds for representing perspectives according to the educational purposes of the program and the professional profile of its graduates. The methodology focuses its attention on the two-dimensional field given by the area of design and time. Despite the rigor with which the methodology of curriculum design was conceived, only two educational aspects were related: the structure of courses and the purposes of professional development. Such a proposal can be seen in Fig. 9.
A project-based curriculum has been defined in Venezuela. The experience describes a sequence of courses, advancing through the development of projects [15]. Fig. 10 shows the proposal.

The term "distance" is conceived for measuring similarities through the Bodies of Knowledge (BOK) on the covered topics. For this purpose, a frequency analysis was performed where the range of distance oscillates between 0 and 1.4 [16]. Fig. 11 shows such a proposal, using one educational aspect related to the course structure.

In the experience of designing a curriculum for the software industry, a vision of systemic thinking was involved [17]. This is another work which prioritizes methodological design rather than the design of the curriculum itself, as shown in Fig. 12. One educational aspect was involved, which is the foundations of the design.

The curricular reorganization led the authors to propose a curricular structure based on a timeline. Fig. 13 shows such a proposal; which courses have the inner information about the assessment. In such a proposal, [18] two educational aspects were included: course structure and assessment criteria.
Another work in Venezuela shows a block-based diagram for course structure [19]. Blocks grouped by components represent the course structure as shown in Fig. 14. Just one educational aspect was included.

Finally, a proposal for standardizing a new undergraduate curriculum for an Information Technology degree at Universities in West China was conceived, by using a progress graph which is representing the course structure. Fig. 15 shows the graphical representation, with courses as nodes and arrows providing the sequential path among them. Just one educational aspect was involved as a course structure.

Given the previous samples of graphical representations, a summary of such proposals can be expressed in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Case</th>
<th>Graphical representation</th>
<th>Educational aspects</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Blocks, arrows</td>
<td>Methodology, syllabi</td>
</tr>
<tr>
<td>2</td>
<td>Blocks, matrices, arrows</td>
<td>Syllabi</td>
</tr>
<tr>
<td>3</td>
<td>Venn's diagram</td>
<td>Educational purposes</td>
</tr>
<tr>
<td>4</td>
<td>Layer-based diagram</td>
<td>Syllabi</td>
</tr>
<tr>
<td>5</td>
<td>Flow-path</td>
<td>Syllabi</td>
</tr>
<tr>
<td>6</td>
<td>Block diagram, activity diagram</td>
<td>Syllabi, Educational purposes</td>
</tr>
<tr>
<td>7</td>
<td>Matrix, blocks</td>
<td>Syllabi</td>
</tr>
<tr>
<td>8</td>
<td>Block diagram</td>
<td>Syllabi</td>
</tr>
<tr>
<td>9</td>
<td>Cloudy areas, hierarchical structure</td>
<td>Syllabi, Educational purposes</td>
</tr>
<tr>
<td>10</td>
<td>Sequential structure</td>
<td>Syllabi</td>
</tr>
<tr>
<td>11</td>
<td>Tree-view</td>
<td>Syllabi</td>
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<tr>
<td>12</td>
<td>Blocks</td>
<td>Methodology</td>
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<tr>
<td>13</td>
<td>Timeline</td>
<td>Syllabi, assessment</td>
</tr>
<tr>
<td>14</td>
<td>Blocks</td>
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<td>15</td>
<td>Blocks, arrows</td>
<td>Syllabi</td>
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Source: The author

4 Proposed solution

Wyner et al. said: “Controlled Natural Languages (CNLs) are engineered languages which use a selection of the vocabulary, morphological forms, grammatical constructions, semantic interpretations, and pragmatics which are found in a natural language” [21]. In this paper, the use of a controlled language called pre-conceptual schemas is proposed. According to Zapata, a pre-conceptual schema is a way to represent knowledge by using a controlled language [22]. Moreover, pre-conceptual schemas use simple notation, they are easy to understand, and they are adaptable to any domain of knowledge [23]. Their notation can be summarized in Fig. 16.
By using pre-conceptual schemas, it is possible to graphically represent any educational aspects. The pre-conceptual schema in Fig. 17 represents the scope of the definition of a curriculum in general.

When recalling a definition of curriculum, which educational aspects involve: methodology, theoretical foundation, context, objectives, syllabi and syllabus, teaching-learning-assessment strategies, and resources [2], it is important to note that the previous graphical representation has three main aspects: Methodology, Content, and Teaching-Learning-Assessment.

In Fig. 17, a general-purpose definition of curriculum is represented, with several educational aspects. Such graphical representation uses just one symbology, this is the pre-conceptual schema.

In order to create a specific orientation towards content in a knowledge area, the usage of templates is recommended.

4.1 Template for methodology aspects (Curriculum Processes)

Curriculum processes are a series of steps that indicate how curriculum development is performed. As its name implies, it is a continuous and systematic process that must be developed in order to reach the goals [24]. In such a stage, the following template for methodology is declared, which has been expressed in a pre-conceptual schema in Fig. 18.

The pre-conceptual schema shows the definition of a general methodology, in which the values of the stages can be altered according to the designer’s criteria.

In this case, the stages of doing research, a background study, and planning with a proper team are described; then, performing the execution of the proposal, and getting some feedback.
4.2 Template for content aspects (Curriculum)

The main content should be referenced from the proposal of the ACM, AIS, and IEEE Computer Society, given the nature of the computing-related undergraduate programs. For a theoretical foundation, there is a great ocean of pedagogical approaches on which to base curriculum design.

The concept of context refers to the study of the geographic and socio-cultural scenario where the curriculum will be applied. Finally, the final educational purposes will be expressed as objectives. The following templates (Fig. 19-20) show such representations. The former deals with the composition of the theoretical background, and the latter deals with the main topics in the field of computing, as the content of the curriculum; it is important to emphasize that the disciplines proposed by the Computing Curricula are a set of 5 well-defined areas of knowledge.

It is important to clarify that it is not intended to build a standard for curriculum design, but rather to use a controlled language to establish a common framework of reference when proposing curricular designs.

According to the previous templates, the theories and paradigms regarding the educational aspects are a finite set. However, pedagogical models and teaching-learning-assessment strategies have been produced in a wide variety.

Fig. 20 represents which of the main topics in the field of knowledge in computing should be considered in the syllabi for a computing-related undergraduate program. This is possible thanks to the guide of the recommendations of the Computing Curricula.

Specific courses can be designed by using the following template as shown in Fig. 21. Such template establishes the way in which a course can be configured. Note that the concept COURSE has an inner structure of attributes; so, they can be adapted according to each program.

Within the symbology of the pre-conceptual schemas, the previous templates have used the values that are the elements that usually change according to each curriculum proposal.
5 Benefits

The use of pre-conceptual schemas simplifies the representation of knowledge through a controlled language. It is a graphical representation which is able to explain any educational aspect using the same symbology.

Given the nature of the pre-conceptual schemas, the possibilities of design are unlimited, when making curriculum proposals, a series of templates that will serve as a design guide is proposed; However, it is not intended to create a model of construction, but to give the guidelines of design orientation.

Pre-conceptual schemas have very specific design rules, which guarantees a clear representation of concepts at the time of designing a curriculum.

6 Conclusions

From their inception, the pre-conceptual schemas were created as an intermediate scenario for automatically obtaining the conceptual graphs for the UML notation. Its field of action has been mainly software engineering, especially the engineering requirements, as a mechanism of representation of knowledge from natural language.

In this paper, it was demonstrated that the pre-conceptual schemas can be used in any scenario where knowledge requires to be represented graphically. In this case, curriculum design benefits from the advantages of using pre-conceptual schemas.

In essence, the problem of heterogeneity of curriculum designs cannot be solved. However, some guidelines to minimize the problem of the lack of communication between computing-related undergraduate programs, by using a common controlled language are described in this proposal.

With the use of pre-conceptual schemas, it is possible to represent any educational aspect using the same symbology. This situation can facilitate the reading and monitoring of curricula, as well as the interaction between them, and their evaluation.

7 Future work

In educational matters, several things remain pending to be worked on. First off, the production of templates represented in pre-conceptual schemas for the design of teaching-learning activities within a classroom would be very interesting.

This paper emphasizes the motivation aspects, which are supremely important to the success of the teaching and learning processes. In this vein, the creation of a repository of ludic activities written entirely in pre-conceptual schemas would be very useful when incorporating classroom activities into curriculum designs. In addition, activities for validating the proposal will be required in the future.

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