CURRICULUM VISUALIZATION BASED ON SUBJECT COMPETENCES

Laia Blasco Soplon[1], Julià Minguillón[1], Javier Melenchón Maldonado[1]

[1] Universitat Oberta de Catalunya (SPAIN)

Abstract

This paper proposes a novel visualization of an academic degree curriculum based on the information about its competences and subjects. The proposed visualization places the subjects closer or further from each other, depending on their shared or non-shared competences. In addition, the resulting graphic shows different clusters, formed by groups of subjects with more common competences. We have applied this visualization to the Multimedia degree and to the Computing Engineering degree of the UOC (Universitat Oberta de Catalunya, known in English as Open University of Catalonia).

Keywords: visualization, curriculum, competences, e-learning

1 INTRODUCTION

Since the creation of the new European Higher Education Area, it has become necessary to shift from heavily content-based courses to others where the activity is the key concept. The activities and the competences students develop by fulfilling such activities have become the focus of any formative action. It is also important to promote the formal acknowledgement of skills, knowledge and competences gained through work experience, informal training and life experience, for prior learning recognition purposes. Following from the Bologna Declaration [1], lifelong learning becomes a clear objective, using a competency-based approach for designing personalized formative itineraries and promoting collaborative work.

Academic degrees or curricula are usually presented with text or tables, following a semester-by-semester structure. This structure helps learners create their own itineraries within a given degree in a global perspective. Both text and tables are useful to explain parts of a specific curriculum, but they are of limited use for visualizing the links between the different subjects, competence acquisition and development, learning outcomes or the activities carried out in each subject. Competences and subjects are fully intertwined but, due to the nature of the enrolment process, learners normally make their decisions based on which courses they want to take only, not the competences they will acquire or develop.

We propose a different way to present an academic degree curriculum, paying special attention to the connections among its various subjects and its competences, and showing the curriculum in a more visual way. It is well known that forming mental images is a prerequisite in human thought, because they give meaning to and organize new information, providing modes of reasoning and decision-making [2]. Visual perception is what allows us to have a true understanding of the experience, considering form and content inseparable [3]. Visualization techniques can be used to provide a shared mental image of an academic degree. In this sense, information visualization is currently a growing field, with a promising future in the educational context [4]. It allows the creation of shared mental images that help us analyze, understand and take decisions about the curriculum design of an academic degree and its development processes.

This paper aims, first, to contribute to a dialectical construction of the academic curriculum [5] by means of data visualization techniques that provide a shared, integrated and holistic vision of that curriculum, and then to assist and improve self-reflection during the curricular design process and also during the teaching-learning process.

This paper is structured as follows. Section 2 describes the e-learning context where this research takes place. In Section 3 the visualization process is developed. Section 4 explains the visualization results and Section 5 suggests some discussion points. Finally, Section 6 presents the conclusions and future work.

2 E-LEARNING CONTEXT

We built the proposed visualization for some degrees of the Universitat Oberta de Catalunya (UOC) [6]. UOC is a completely online university which offers 15 official degrees, 18 official masters, several graduate programs and post-graduate studies, and 3 doctoral degrees, with more than 50.000 students and more than 4.000 workers including instructional designers, teachers, tutors, academic and technical staff, and so [7]. The UOC virtual campus is an integrated e-learning environment which allows users to communicate with other users using a mail system with complete timetable independence, following the institutional asynchronous approach, and includes an agenda, virtual classrooms and laboratories, a digital library and other e-learning related tools. UOC has a student centered pedagogical model that ensures a guided learning path through the use of selected learning resources, according to the experience of a team composed of instructional designers, usability experts and, of course, teachers.

In this way, we start from an extra necessity. The e-learning context, as a whole, requires more tools than those included in the classroom context in order to carry out the same teaching-learning processes. Because communication is neither face-to-face nor asynchronous, additional support is needed in the virtual communication. The curriculum could be one of these tools: it contains the information from which students start to know what the degree is, and it is also the guide that makes possible coordination among teachers, managers, etc. Thus, the curriculum is an important communication tool that needs to evolve and improve [6].

3 THE VISUALIZATION PROCESS

The main contribution of the proposed visualization is to show the relationship between all the subjects in a degree through their shared competences. To this end, we present a network visualization consisting of all the degree subjects. More specifically, we paint a graph visualization, in which the distances between the different subjects are calculated according to their shared and non-shared competences. Therefore, subjects with more common competences are nearer than other subjects with fewer common competences, and subjects without any common competences are not linked at all. Moreover, we obtain graphs with different groups or clusters of subjects with more common competences.

3.1 Data collection

We begin the process with the Multimedia degree curriculum, a European Higher Education Area degree composed by 240 ECTS, working on 23 competences, organized into 54 subjects. To build this curriculum visualization we start with a table in an Excel file that expresses the common competences (columns) shared by the 54 subjects (rows).

The following table (Fig. 1) defines a bipartite graph between subjects and competences. Each subject may develop one or more competences, while each competence may be developed through one or more courses. In this first stage of analysis, we will not take into account how these competences are acquired and/or developed and to what extent: we are just interested in establishing binary relationships between subjects and competences. Although we could transpose rows and columns, we will focus on grouping subjects according to their developed competences.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	Trabajo en equipo en la red	1	1	1															1					
2	Programación													1										1
3	Lenguajes y estándares web								1				1	1	1									
4	Diseño gráfico			1		1	1		1													1		
5	Vídeo		1			1	1	1				1												
6	Inglés I				1																			
7	Matemáticas para multimedia I								1		1												1	1
8	Programación web												1	1		1								
9	Imagen y lenguaje visual					1	1		1													1		
10	Narrativa interactiva	1					1	1																
11	Inglés II				1																			
12	Matemáticas para multimedia II								1			1					1				1		1	1
13	Administración y gestión de las organizaciones																			1		1		
14	Gráficos 3D						1		1		1													
15	Arquitectura de la información						1	1		1					1									
16	Competencia comunicativa para profesionales de las TIC	1																						
17	Física para multimedia								1														1	1
18	Fundamentos y evolución de la multimedia		1			1	1			1								1		1				1
19	Animación		1			1	1	1			1													
20	Diseño de interfaces multimedia						1		1	1														
21	Integración digital de contenidos											1	1	1				1			1			
22	Redes multimedia															1	1				1			
23	Diseño de bases de datos													1	1									1
24	Medios interactivos		1			1	1	1				1												
25	Tratamiento y publicación de imagen y vídeo					1						1	1	1			1	1					1	1
26	Tratamiento y publicación de audio					1						1	1	1			1	1					1	1
27	Composición digital		1			1	1	1				1												
28	Gestión de proyectos	1																	1			1		
29	Mercado y legislación	1																1		1		1		
30	Metodología y desarrollo de proyectos en red	1		1		1													1		1			
31	Fotografía digital		1			1	1		1			1												
32	Creatividad y estética	1				1	1		1				1											
33	Animación 3D		1			1	1	1			1													
34	Visualización de información								1	1			1		1									
35	Plataformas de publicación y distribución					1						1	1			1	1	1			1		1	
36	Uso de bases de datos													1	1									1
37	Sistemas de gestión de contenidos												1	1	1	1		1						
38	Documentación audiovisual	1	1			1													1					
39	Programación web avanzada												1	1	1	1								
40	Aplicaciones RichMedia												1	1										
	Uso de bases de datos													1	1									1
41	Seguridad y calidad en servidores web															1		1			1			
42	Comportamiento de usuarios				1					1			1		1			1						
43	Usabilidad					1				1								1						
44	Realidad virtual								1	1	1					1								
45	Diseño de la interacción						1	1		1			1											
	Programación web avanzada												1	1	1	1								
46	Ingeniería del software													1		1								
47	Análisis y diseño con patrones													1		1								
48	Diseño y programación orientada a objetos													1		1								
49	Prácticas I		1			1														1	1	1		
50	Prácticas II		1			1														1	1	1		
51	Trabajo final de grado I	1					1											1	1		1			
52	Trabajo final de grado II	1					1											1	1		1			
53	Inglés III				1																			
54	Iniciativa emprendedora y dirección de organizaciones	1					1													1		1		

Fig. 1 Table of subjects (rows) and competences (columns) of the Multimedia degree

3.2 Calculating distances

The next step of our analysis is establishing a distance function between subjects, depending on the competences they help to develop. Due to the nature of competences and subjects (there are no subjects that develop all the competences, and there are no competences developed by all subjects), we will use the following premises:

- The more competences two different subjects share, the “closer” they are. Let NSC be the number of competences shared by the two subjects.
- The more competences differ between two different subjects, the more “distant” they are. Let NDC1 and NDC2 the number of competences developed in subject 1 and not developed in subject 2 (and vice versa), respectively.
- Competences that are not developed in either one subject or the other should not be taken into account.

Therefore, we will select as the distance function between subjects a measure of similarity [8] based only in these three terms, NSC, NDC1 and NDC2, namely:

- Jaccard: NSC / (NSC + NDC1 + NDC2)
- Dice: NSC / (2*NSC + NDC1 + NDC2)
- Kulzinsky: NSC / (NDC1 + NDC2)
- Sokal-Sneath-e:0.5 * NSC * (1 / (NSC + NDC1) + 1 / (NSC + NDC2))
- Ochiai: NSC / sqrt((NSC + NDC1) * (NSC + NDC2))

All these similarity measures grow with NSC and decrease with NDC1 and NDC2. Except for the Kulzinsky measure, all of them are in the range [0, 1]. We have chosen the Jaccard index for exploration purposes in this preliminary experiment.

Notice that these measures are symmetrical in the sense that d(S1, S2) = d(S2, S1). Therefore, we can build a symmetrical matrix (only the lower diagonal) computing d(S1, S2) for all S1 < S2, understanding that there is some implicit order between subjects. d(S, S) is, by definition, zero. We use this matrix as a weight matrix for the graph containing all the subject combinations with, at least, one competence in common, that is, d(S1, S2) > 0.

3.3 Drawing the graph

The next step is drawing the graph. We use Gephi [9], an interactive visualization and exploration platform for networks and complex systems. We have taken the curriculum as a network, because we consider it an interconnected system. In this scenario, the subjects are nodes and the links between them are edges. The graph is undirected because edges have no orientation (the relationship “sharing a competence” is symmetric).

Then we calculate the graph modularity, a measure of the structure of networks and graphs, designed to gauge the strength of division of a network into modules (also called groups, clusters or communities). Calculating the modularity allow us to make the modularity partition and obtain different coloured clusters.

Finally, we apply the Force Atlas 2 distribution because it is the best for distinguish all subjects and the entire structure at the same time [10].

We obtain a graph (Fig. 2) with 4 clusters painted blue, red, green and violet.

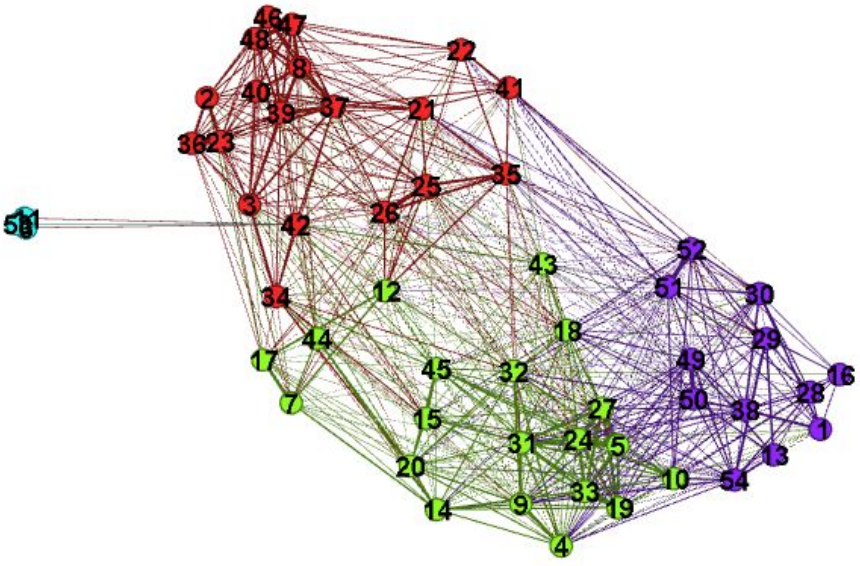

Fig. 2 Multimedia degree graph

Then, we follow the same process with the Computing Engineering degree curriculum, another European Higher Education Area degree composed by 240 ECTS, working on 20 competences, organized into 57 subjects (Fig. 3).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Fundamentos de programación																	1			
2	Prácticas de programación																	1			
3	Álgebra											1	1								
4	Análisis matemático											1	1								
5	Fundamentos físicos de la informática											1	1								
6	Trabajo en equipo de la red	1	1		1																
7	Fundamentos de computadores													1							
8	Administración y gestión de organizaciones								1		1										
9	Estadística											1	1								
10	Lógica											1	1								
11	Competencia comunicativa para profesionales de las TIC	1																			
12	Idioma moderno I: Inglés I			1																	
13	Idioma moderno II: Inglés II			1																	
14	Diseño y programación orientada a objetos																	1			
15	Ingeniería del software																		1	1	
16	Sistemas operativos													1	1		1	1			1
17	Uso de base de datos																			1	1
18	Grafos y complejidad											1	1								
19	Gestión de proyectos	1					1	1		1	1										
20	Redes y aplicaciones Internet														1	1	1				
21	Estructura de computadores													1	1	1					
22	Inteligencia artificial												1								1
23	Administración de redes y sistemas operativos													1	1		1				1
24	Interacción persona ordenador							1										1	1		
25	Diseño de bases de datos																			1	1
26	Sistemas distribuidos														1	1				1	1
27	Trabajo de fin de grado	1	1			1	1	1		1											
28	Seguridad en redes de computadores										1				1	1					1
29	Estructura de redes de computadores														1	1	1				1
30	Diseño de redes de computadores														1	1	1				1
31	Diseño de sistemas operativos													1	1		1	1			1
32	Sistemas empotrados														1	1	1	1			1
33	Arquitectura de computadores													1	1						1
34	Arquitecturas de computadores avanzadas					1	1			1			1		1						1
35	Diseño de estructuras de datos												1					1			1
36	Ingeniería de requisitos																	1	1		1
37	Análisis y diseño de patrones																	1	1		1
38	Ingeniería del software de componentes y sistemas distribuidos																	1	1		
39	Proyecto de desarrollo del software				1		1	1					1					1	1	1	1
40	Autómatas y gramáticas											1	1					1			
41	Compiladores												1					1		1	1
42	Representación del conocimiento												1							1	
43	Aprendizaje computacional												1								1
44	Minería de datos											1	1								1
45	Iniciativa emprendedora y dirección de organizaciones	1					1		1		1										
46	Fundamentos de sistemas de información	1							1												
47	Integración de sistemas de información	1				1		1	1	1								1			1
48	Uso de sistemas de información en las organizaciones	1			1		1	1	1	1	1										
49	Gestión funcional de servicios SI/TI	1				1		1		1	1										
50	Dirección estratégica de SI/TI	1				1	1		1	1	1										
51	Criptografía					1				1		1									1
52	Comercio electrónico									1						1				1	1
53	Modelado de sistemas					1						1	1								1
54	Arquitectura y administración de bases de datos									1					1					1	1
55	Iniciación a las matemáticas para la ingeniería											1	1								
56	Data warehouse											1	1								
57	Prácticas en empresa	1	1			1	1	1			1										

Fig. 3 Table of subjects (rows) and competences (columns) of the Computing Engineering degree

In this case we obtain a graph (Fig. 4) with 5 clusters painted violet, blue, red, light and dark green.

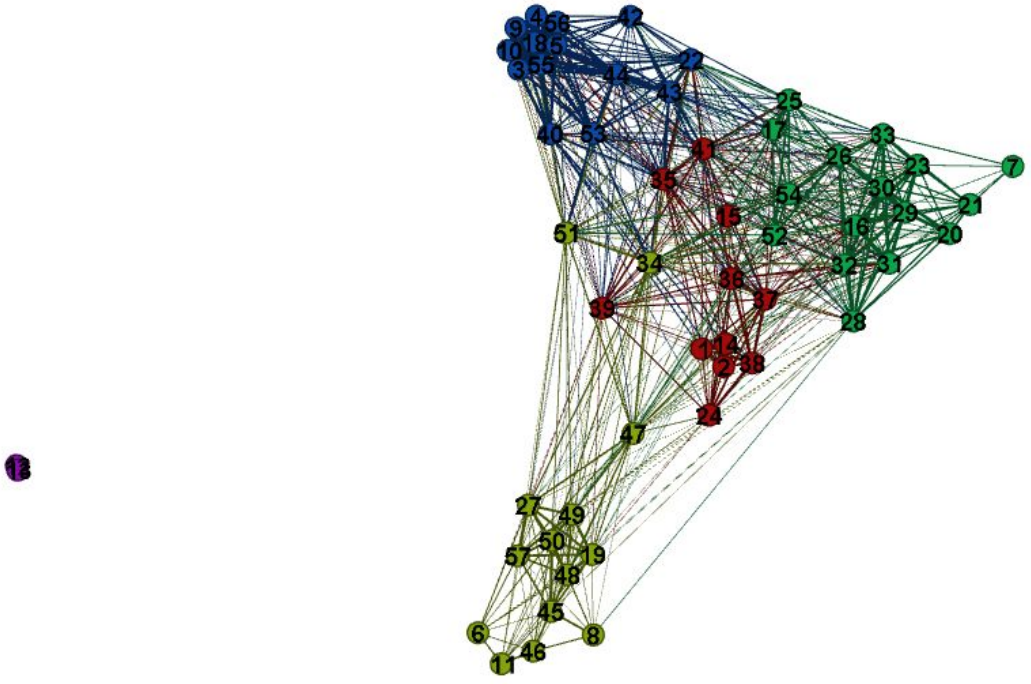

Fig. 4 Computing Engineering degree graph

4 RESULTS

For both graphs, a set of clusters can be found. One lecturer of each degree has analyzed the degree visualization and named each individual cluster with a keyword representing the common topic among the subjects that compose each cluster.

In the case of the Multimedia degree, the 4 clusters were named as follows:

- Group A (violet): Management
- Group B (green): Design
- Group C (red): Technology
- Group D (blue): English

In Fig. 2, we can observe that subject 30 (Methodology and development of networked projects) is placed in one of the outer ends of the Management cluster (violet), while subject 4 (Graphic design) is placed in one of the outer ends of the Design cluster (green), and subject 46 (Software engineering) is placed in one of the outer ends of the Technology cluster (red). The three English subjects (6, 11, 53) are isolated in a single cluster (blue) and they show little relationship with the other groups of subjects according to this methodology. Subjects such as 43 (Usability), 35 (Publishing and distribution platforms) or 45 (Interaction design) are placed on the centre of the graph, because they are more central the three big parts of the degree (Management, Design and Technology).

In the case of the Computing Engineering degree, the 5 clusters were named as follows:

- Group A (light green): Information systems
- Group B (red): Programming languages and compilers
- Group C (dark green): Hardware and systems architecture
- Group D (blue): Foundations of computer science
- Group E (violet): English

In Fig. 4, we can observe that subject 6 (Networked teamwork) is placed in one of the outer ends of the Information systems cluster (light green), while subject 38 (Software engineering of components and distributed systems) is placed in one of the outer ends of the Programming languages and compilers cluster (red), subject 21 (Computers structure) is placed in one of the outer ends of the Hardware and systems architecture cluster (dark green), and subject 10 (Logic) is placed in one of the outer ends of the Foundations of computer science (blue). Both English subjects (12,13) are isolated in a single English cluster (violet) and they do not show any relationship with the other groups of subjects. Subjects such as 34 (Advanced computer architectures), 39 (Software development project), 41 (Compilers) or 15 (Software engineering) are placed in the centre of the graph, because they are more central to the four big parts of the degree (Information systems, Programming languages and compilers, Hardware and system architecture and Foundations of computer science).

5 DISCUSSION

The proposed visualization can help to take snapshots of the degree during its design process, and thus it can help teachers and degree managers make strategic decisions from a different point of view and in a holistic way during the degree design process.

Furthermore, this proposal could be used as a technique for analyzing the competence based implementation of an already developed degree. The shape of the graph, or the subjects that make up such clusters, may become evidences of the design and development curriculum style, its competences distribution and its subjects attributes [11].

Moreover, the proposed degree visualization seems to be useful to three types of agents involved in the teaching-learning process: students, teachers and management staff. The visualization of the relationships between the different subjects helps to place each student in a degree general map; it

also helps to place teachers who teach the subjects regarding the relationships with other subjects and other teachers; finally, it also helps to provide the management staff (dean, programme/degree director or technical assistants) with an overall picture that may help them to get a better understanding of the degree development.

In the same way, this visualization could be the basis for developing a more complex graphic design proposal showing the curriculum through a useful and browsable visual map. It also has potential to become an interactive interface in which the paths of students can be shown, and it may reflect the evolution of the degree with the passage of time.

6 CONCLUSIONS AND FUTURE WORK

In conclusion, the proposed visualization of the curriculum of the Multimedia and Computing Engineering degrees places the subjects in a visual space with respect to the information about its competences, placing them closer or further away depending on the common competences. This visualization also distinguishes different related subject groups based on their shared competences. Therefore, the proposal aims to help to place students, teachers and managers in a degree general map. Moreover, it could also contribute as a way to take snapshots of the whole degree during its design process, or even as a technique for analysing the competence based implementation of an already developed degree.

Starting from here, we are planning to work on two lines of research: asking students, teachers and managers about the utility of the proposed visualization in order to enhance the visualization and build an open curriculum degree visual design, and providing interactivity to a curriculum interface to show the paths of students along the semesters.

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