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2. A brief history of the founding of an emblematic university in the rain forest of Ecuador and an innovative approach to the design and planning of academic curricula for Latin America

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ABSTRACT

The marginal role of higher education in Latin America led to technological dependency, poor economic growth, and social inequity. In the article, we discuss the challenging context in which higher education in Latin America developed and explain the motives behind the creation of a public university in the tropical rain forest of Ecuador. New and reformed higher education institutions in Latin America require innovative approaches to design academic programs and implement novel educational paradigms. We propose a quantitative and unorthodox method for analyzing the structure of program curricula in this historical and social context. This approach highlights the need for strategic academic planning and informed public policies. The inherent variation in program curricula across universities can be systematized in a presence-absence matrix, with courses and academic programs as columns and rows. By representing the patterns of variation in curricular structure across universities in the space provided by canonical axes, new perspectives arise which can lead to the development of further discussions towards optimal and innovative academic programs. The methods presented could be extended into the study of how academic disciplines, fields of study, and conceptual approaches to the design of program curricula vary and are structured across sociocultural contexts.

Keywords: Educational Policy; Curriculum Organization; Educational Planning; Ecuador

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Breve historia de la fundación de una universidad emblemática en el bosque tropical del Ecuador y un método innovador para el diseño y planificación de programas curriculares académicos para América Latina

RESUMEN

La función marginal de la educación superior en América Latina ha dado lugar a la dependencia tecnológica, al bajo desarrollo económico y a la inequidad social. En este artículo, discutimos el complejo contexto en el que la educación superior en América Latina se desarrolló y explicamos los motivos de la creación de una universidad pública en la selva tropical amazónica del Ecuador. Las nuevas y reformadas instituciones de educación superior en América Latina requieren prácticas innovadoras para diseñar programas académicos e implementar nuevos paradigmas educacionales. En este contexto histórico y social, se propone un método cuantitativo y novedoso para analizar la estructura de los programas curriculares. Este método subraya la necesidad de contar con una planificación estratégica académica y con políticas públicas informadas. La variabilidad en las mallas curriculares entre universidades puede ser sistematizada en una matriz de presencias y ausencias, con cursos y programas académicos en columnas y filas. Al representar los patrones de variación curricular entre universidades en el espacio provisto por ejes canónicos, surgen nuevas perspectivas para el desarrollo de discusiones que generen programas académicos innovadores y óptimos. Este método puede extenderse al estudio de como varían los programas académicos, los campos de estudio y las aproximaciones conceptuales del diseño de las mallas curriculares y como éstos son estructurados en diversos contextos socioculturales.

Palabras clave: Política en Educación, Organización Curricular, Planificación Educativa, Ecuador.

Uma breve história da fundação de uma universidade emblemática na floresta tropical do Equador e uma abordagem inovadora para o desenho e planejamento de programas curriculares acadêmicos para a América Latina

RESUMO

O papel periférico do ensino superior na América Latina leva à dependência tecnológica, ao fraco crescimento econômico e à desigualdade social. No presente artigo, discutimos o contexto desafiador no qual o ensino superior na América Latina se desenvolveu e explicamos os motivos por trás da criação de uma universidade pública na floresta tropical do Equador. Instituições de ensino superior novas e reformadas na América Latina exigem abordagens inovadoras para projetar cursos acadêmicos e implementar novos paradigmas educacionais. Nesse contexto histórico e social, propomos um método quantitativo e não ortodoxo para analisar a estrutura dos currículos dos cursos;. Essa abordagem mostra a necessidade de planejamento acadêmico estratégico e de políticas públicas informadas. A variação inerente na grade curricular entre as universidades pode ser sistematizada em uma matriz de presença e ausência, com matérias e programas acadêmicos com colunas e linhas. Ao representar os padrões de variação da grade curricular entre as universidades no espaço proporcionado pelos eixos canônicos, novas perspectivas surgem para o desenvolvimento de discussões adicionais que levem a cursos acadêmicos ótimos e inovadores. Os métodos aqui apresentados podem ser estendidos ao estudo de como as disciplinas acadêmicas, os campos de estudo e as abordagens conceituais para o desenho dos currículos dos programas variam e são estruturados em diferentes contextos socioculturais.

Palavras-chave: Política Educacional; Organização Curricular; Planejamento Educacional; Equador.

Brève histoire de la fondation d'une université emblématique dans la forêt tropicale équatorienne et présentation d'une approche innovante de la création et la planification des programmes académiques en Amérique Latine

RESUMÉ

Le rôle marginal de l'enseignement supérieur en Amérique latine entraîne une dépendance technologique, une faible croissance économique, et des inégalités sociales. Dans cet article, nous discutons le contexte dans lequel l'enseignement supérieur en Amérique latine s'est développé et nous expliquons les motivations pour la création d'une université publique dans la forêt tropicale humide de l'Équateur. Les établissements d'enseignement supérieur nouveaux et réformés en Amérique latine ont besoin des approches innovantes pour le design des programmes universitaires, et la mise en œuvre de nouveaux paradigmes éducatifs. Dans ce contexte historique et social, nous proposons une méthode quantitative et peu orthodoxe pour analyser la structure des programmes d'études. Cette approche montre la nécessité d'une planification académique stratégique ainsi que des politiques publiques bien informées. La variation inhérente aux programmes d'études entre les universités peut être systématisée dans une matrice en présence-absence, avec des cours et des programmes universitaires basés sur des colonnes et des rangées. En considérant les modèles de variation des programmes d'études entre les universités dans l'espace des axes canoniques émergent des nouvelles perspectives pour le développement des discussions menant vers des programmes académiques plus optimales et innovantes. Les méthodes ici présentées pourraient servir à analyser la variation des disciplines académiques, des domaines d'études et des approches conceptuelles en matière de design des programmes d'études mais aussi à montrer comment ils sont structures dans les différents contextes socioculturels.

Mots clés: Équateur; Organisation des Programmes Universitaires; Planification de l'Enseignement; Politique Éducative.

1. INTRODUCTION

From the time of their establishment in the sixteenth century up to the second decade of the twentieth century, higher education institutions (HEIs) in Latin America remained under the authority of colonialist royal crowns, the traditional Catholic church, and families of the oligarchy whose economic power was not grounded in the pursuit of innovation but the predatory export of raw materials (Brock, 1981; Carvalho y Flórez-Flórez, 2014). We can say that, in this way, early Latin American universities conformed to the 'elite model' of Trow (2007, p. 243), which was designed to service the ruling classes and prepare them for leading positions in society. This model has persisted.

An economy based on primary products subsists today in most Latin American nations as their economies are focused mostly on the export of unprocessed materials and goods with little value added in knowledge and technology (Bértola y Ocampo, 2015; Vega-Jurado, Fernández-de-Lucio y Huanca, 2008). The industrial revolutions of the 18th and 19th centuries were social, economic, and scientific processes that took place mostly in Europe and North America and increased the demand for raw materials. Consequently, these industrial revolutions perpetuated the economic model based on primary commodity exports of most countries in the southern hemisphere. Consequently, HEIs in this region remained excluded from the development of new ideas, reinforced their detachment from scientific inquiry and innovation, and were not agents of societal change (Arocena y Sutz, 2005). This legacy persists today as demonstrated in the fact that only 62 of the 16,000 HEIs in Latin America are considered research institutions (González, Espinoza y Bergegal Mirabent, 2015).

It was not until the emergence of liberal ideas at the beginning of the 20th century, represented by a diverse array of political movements and rebellions across the Latin American region, that HEIs began to transform into more inclusive and socially committed institutions (Bernasconi, 2008). However, during the 20th century, there were negative factors which affected the relationships between academic institutions and mainstream scientific inquiry, state governments, and private industry. These include a marginal insertion into global markets, a long hiatus in free-thought due to the Spaniard and Portuguese legacy of scholastic tradition, and the subsequent political upheavals amongst leftist revolutionary movements and right-wing military dictatorships, in which Latin

American universities played an influential role (Arocena y Sutz, 2005). For example, the University Reform Movement (URM) which took place in the first half of the twentieth century and is considered the only academic revolution to have happened in Latin America, was a process through which HEIs in the region became active participants in social reform. However, it also fostered tensions and divisions between governments and private firms (Vega-Jurado et al., 2008). This division between universities and private enterprise continues to this day.

The dependency on imported technological products, the lack of demand for research and innovation by private enterprises, and the consequences of the historic, economic, and cultural legacy in which South American HEIs evolved, produced a self-reinforcing mechanism that fostered politicization, quality impairment, lack of relevance, and chaotic massification in admissions (Bernasconi, 2008; Fischman y Ott, 2018). This university environment dissuaded efforts in research and innovation, thereby prejudicing national economies and welfare. For example, one of the consequences of massification in admissions has been the increasing proportion of faculty members employed on a part-time basis (e.g., 86% in Argentina) and the low proportion of staff with PhD degrees (less than 15% for the region), (González et al., 2015). The consequences of having transitory professors and very few qualified scientists have been a significant lack of commitment to scientific research and continued emphasis on traditional teaching (González et al., 2015).

During the 1980s, neoliberal models, spearheaded by the International Monetary Fund and the World Bank, considered higher education an individual benefit, but not a social good nor a driver of societal change (Fischman y Ott, 2018). Such a localized worldview constricted financial support for public universities and relaxed the necessary prerequisites and incentives for scientific development. Today, higher education in Latin America faces challenges that include antiquated teaching methods, incoherence vis-a-vis labor markets, dependency on political agendas, academic parochialism, and inefficient administrative systems (Fischman y Ott, 2018).

With the onset of post-neoliberal governments in some countries in Latin America, higher education experienced widespread revaluation of neoliberal policies (Levy, 2011), and attempted to transform long-held economic systems into knowledge-based and innovation-driven economies (Peralta y Pacheco, 2014). In this new scenario, HEIs should strive to fulfill the needs of the Latin

American society and become significant players in economic growth by generating, transmitting, and applying advanced knowledge (Arocena, Göransson y Sutz., 2015; Uribe-Roldán, 2015).

Following the historical inadequacies of HEIs in Latin America, universities in Ecuador have been traditionally disconnected from scientific inquiry and committed to replicating knowledge produced elsewhere (van Hoof, 2015). The past two decades in Ecuador were witness to administrative chaos and further impoverishment in the quality of higher education. According to Jameson (1997, p. 273), higher education in Ecuador subsisted in a system that was 'impossible to explain, to evaluate, or to defend on the grounds of equity, efficiency, quality' or its contribution to national development. Universities in Ecuador operated in a vacuum of authority, with no coherent national plan or direction as to how the country should be built; each Ecuadorian HEI acted according to their commitments and agendas, without considering their contribution to the betterment of the nation (Feyen y Van Hoof, 2013). Because of this historical legacy, universities in Ecuador currently have the lowest scores in Latin America for research output, quality of research institutes and education systems, technological readiness, and innovation (Feyen y Van Hoof, 2013).

In 2008, in an effort to remove this deficiency in HEIs, the Ecuadorian government initiated a series of reforms to the national education system, including a new education law (issued in October 2010) that regulates how universities operate in the country (Johnson, 2017). An international recruitment program for highly qualified science specialists (the Prometheus Program) was also implemented at the same time (Serrano et al., 2015). These changes were 'rapid and invasive' and impacted on nationwide accountability processes, admission strategies, faculty qualifications, and research priorities (van Hoof, 2015, p. 58). Another significant component of this reform has been the creation of four new state universities, which the central government described as emblematic projects. By establishing new standards of academic quality in the country, under the entrepreneurial universities model, these new state-sponsored HEIs were expected to foster a stronger academic culture in Ecuador and consolidate an entrepreneurial-knowledge-based society (Paez-Aviles, Juanola-Feliu y Samitier, 2014).

The Universidad Regional Amazónica Ikiam (commonly referred to as Ikiam, which means 'jungle' in Shuar Amazonian language), is one of the four public universities recently established in Ecuador. Ikiam was positioned at the intersection between the lowest eastern hills of the Andean Cordillera and the Amazon Basin, near the city of Tena. Its geographical location, amidst a region rich in biological resources, makes this university an ideal site for the innovation of biotechnological applications and the management of natural resources. The design of several new academic programs was required for the development of this new university.

The conception of an academic program and its curriculum

In 2014, Ecuadorian government authorities and technical specialists in higher education concluded that the design and implementation of a Biotechnology study program was a priority for Ikiam. Initially, the concept was that the Biotechnology program had to include a combination of components related with the following disciplines or areas of knowledge: Biotechnology, Molecular Biology, Bioprospecting, Pharmaceutics, and Biocommerce. Additional requirements of the program included aspects related to Bioengineering and Biomaterials. The prospective Biotechnology program required an original curriculum, not offered in similar university programs in Ecuador. Thus, the design of the Biotechnology program curriculum could not imitate previously existing program curricula, nor be subject initially to subjective or personal criteria. Therefore, an objective method was sought to assist in the design of a new Biotechnology program.

At the outset, there was lack in clarity regarding the availability and sequencing of courses, or the proportion and relative importance of academic disciplines previously identified as relevant prospective components of the Biotechnology program (e.g., Biotechnology or Molecular Biology). Also, not all these academic disciplines were fully compatible or could be exhaustively covered during the nine semesters or academic terms that were expected to represent the prospective undergraduate study program for Ikiam as a new university. Government regulations determined that the study program must be circumscribed within nine terms, each consisting of 16 weeks.

Even though there was a general profile for the prospective Biotechnology program, the overall curricular structure was unknown and needed to be designed. Also unknown was how the various academic programs at other universities related in terms of curricular structure, and how much information was shared in terms of their content. For example, how far apart in their curricular structure was a program in biomanufacturing from a program in pharmacology? Was biocommerce similar enough in curricular structure to biotechnology, to justify an attempt to merge their contents for the new program under design?

For some, these questions may have seen too obvious, but at the time it was necessary to provide objective evidence in support of arguments. It was therefore required to first understand the curricular structure of those academic programs worldwide that were considered essential models or references for the design of the new Biotechnology program curriculum for Ikiam university.

We sampled Academic programs in universities around the World for their curricular structures. The information was recorded and systematized in a data matrix and its variation quantified and analyzed through statistical ordination methods. Such a quantitative and statistical approach provided a synthesis of the most common courses and course sequence structures that were present in available curricula for academic programs around the world.

The statistical methods also allowed for the establishment of an initial program outline that was free from philosophical or idiosyncratic decisions. This initial outline could then serve as the basis for further theoretical and conceptual discussions, and be framed within cultural and socio-economic circumstances, as was the case of Ikiam, a research university in the Amazonian region of Ecuador.

The final product would take the form of a study program curriculum evaluated by us from a quantitative perspective, using the robust framework provided by statistical sampling and comparison.

We used statistical ordination methods to

1) describe how academic programs related to each other according to their curricular structure,

2) determine which courses were shared among different academic program curricula, and

3) establish academic areas of knowledge applying ordination methods in statistics.

We proposed this analytical method in statistics to assist in the design of academic program curricula and provide the basis for strategic academic planning and informed public policies in higher education. Our proposed method, when applied to the study of academic programs and their curricula, will be representative of the structure of higher education around the World.

2. METHOD

We selected a total of 45 academic programs worldwide and their 285 courses as samples for creating an initial data matrix. The selection was not random. In fact, these academic programs were selected for the sampling process because they were useful sources of information given the design interests of the program under construction. These are programs offered by prominent scientific and academic institutions and cover a wide range of cultural backgrounds of geographic relevance. We sought to include in the analysis a broad spectrum of countries and approaches to curriculum building. The analyses were carried out in XLSTAT version 2015 (Addinsoft, 2015).

The data matrix on which these results were based is freely available from the original source. This data matrix included programs as rows and courses as columns. The structure of the data matrix consisted of a sequence of numerical zeros and ones corresponding to the absence or presence of specific courses included in each university program.

The pattern recorded in the data matrix contained pertinent information for the design of new curricula and was interpreted through statistical analyses. As the goal of the analysis was to design a core biotech program, we did not include courses related to social and human sciences that were present in some of the sampled programs. Among the different universities that we sampled in this study, various courses contained similar topics (e.g., Cellular Biology and Biology of the Cell, essentially the same).

The core contents of these courses and their scheduling in specific terms or semesters were deemed similar enough to establish commonalities between them and for this reason they were grouped under a single column in the data matrix.

3. RESULTS

3.1. Distances and spatial arrangement

One product of the data matrix was the distances (or proximities) among academic programs, that explained how dissimilar (or proximal) programs were according to the structure of their curricula. This set of quantitative values was expressed as a diagonal matrix and was the source for a graphical representation of the space spanning the set of distances among programs. In this case, Kulczynski proximities served as the basis for a metric multidimensional scaling (MDS) on two dimensions, as proposed by Hennig y Hausdorf (2006) (Figure 1).

The distribution of programs in the space of figure 1 showed considerable spread. However, it was possible to establish regions of such a space as areas of knowledge.

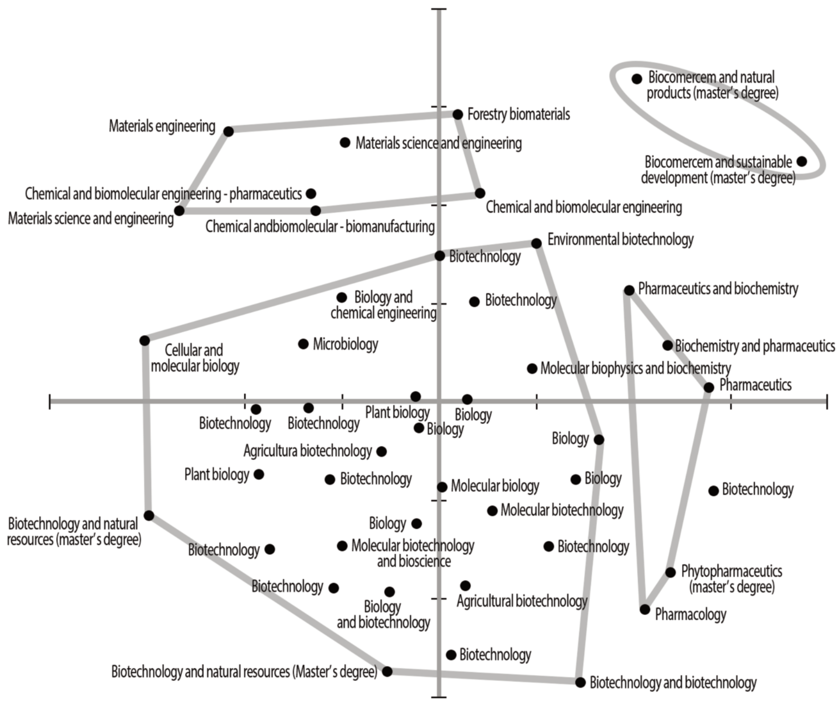
The two biocommerce programs included in the sample form a cluster that is distinct from the other three groups of programs.

The largest group, at the center of figure 1, contained a diverse set of programs associated with biotechnology and biology, with no definite structure within its boundaries. However, the former was reasonably distinct from a group formed mostly by pharmaceutics programs (center-right of Figure 1) and a group composed of bioengineering and biomanufacturing (upper-left of Figure 1).

The differences in academic programs curricula could be self-evident for experts in the field; yet, as both groups of academic programs are considerably distant from each other in the MDS, substantial effort will be required to combine biotechnology and biocommerce in a single course curriculum. The former was a proposal made during the initial steps of the design.

Not all cases conformed to the overall division of groups proposed in Figure 1. There was a biotechnology program that cannot be reasonably included in any of the four proposed groups, as it stood alone to the right of the group of pharmaceutics programs. The curricular structure of this biotechnology program requires further study but should have a greater emphasis on pharmacological aspects than other biotechnology programs that we analyzed in this study.

Figure 1. The results from an MDS analysis depicting distances among academic programs according to their curricular structure. We used grey lines to delimit suggested groups.



3.2. Clustering academic programs

A graphical approach to interpreting similarities shared among academic programs was to order their corresponding distances into a hierarchical cluster analysis (Figure 2). To infer clusters, we applied an unweighted arithmetic average clustering (UPGMA) on Kulczynski proximities as defined by Legendre y Legendre (2012). In this specific instance, it was possible to establish 12 groups of programs according to their similarities at a cut-off point between 0.46 and 0.36 in the Kulczynski proximity scale, which was represented by a dotted line in Figure 2. This cut-off point was where among-group variance reached a maximum value as a ratio of within-group variance and was considered an optimality criterion for defining groups in the dendrogram.

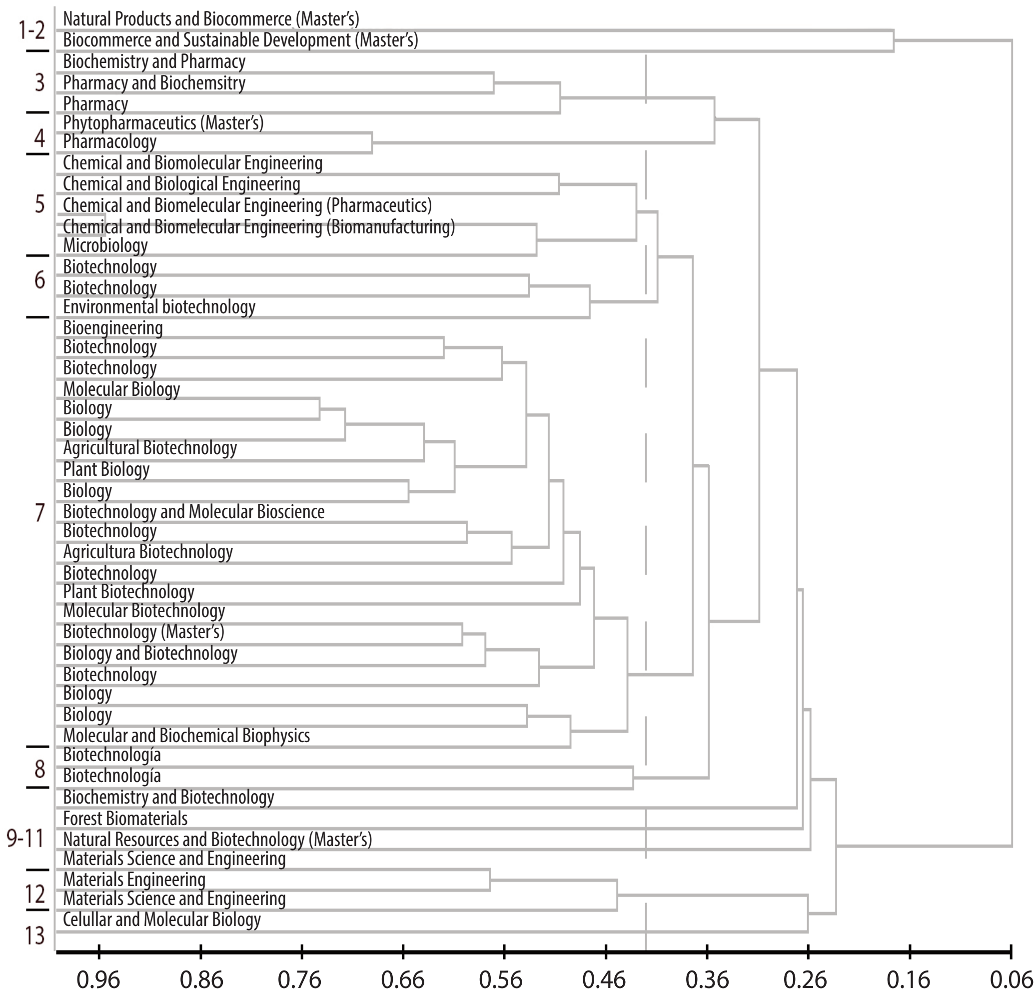
In the dendrogram depicted in Figure 2, Biocommerce programs (Groups 1 and 2) have the lowest similarity overall to other groups of programs, as they cluster last. Pharmacy forms a distinct cluster (Group 3) that has affinities to the cluster containing Pharmacology and Pharmaceutics (Group 4). Engineering programs in Chemistry and Molecular Biology cluster together in group 5. The latter group also contains a Microbiology program. Group 6 comprises three programs in Biotechnology that have a curricular structure dissimilar enough to be distinguished from Group 7. The latter is formed mostly by programs in Biology and Biotechnology. However, Group 7 contains also Bioengineering and Biophysics programs. Group 8 is formed by two Biotechnology programs that are more similar to each other than to the rest of the Biotechnology programs in Group 7. Groups 9 to 11 and 13 are formed by individual programs each. Finally, Group 12 contains Engineering programs in Materials Sciences.

The cluster analysis and its resulting dendrogram in Figure 2 provided an overview from which it was possible to establish how the program curricula related in terms of their similarities. It also provided a criterion as to which groups of academic programs could serve better for the design of new program curricula. For the case of the present example, the analysis provided clarification that programs in Biocommerce had a curricular structure quite distinct from those in the biotechnological area. Merging Biocommerce and Biotechnology in a single academic program was a proposal made at an early phase of the design process, but the evidence on their substantial differences suggested dropping this initial idea.

3.3. Programs and courses as areas of knowledge

An additional method for the study of relationships among programs was to combine the similarities (or differences) between both programs and courses in a single space. By using the information contained in the data matrix, a correspondence analysis (CA) provided the opportunity to interpret affinities within and among programs and courses. The applied CA produced biplots formed by axes that represented how frequent (or infrequent) were the courses in particular programs and vice versa, and where it was possible to establish areas of similarity for academic program curricula (figures 3 and 4).

Figure 2. The results from a cluster analysis depicting a total of 13 groups of academic programs according to their similarities in curricular structure. Group numbers are at the left of each cluster. The vertical dotted line represents a cut-off value along the proximity scale for determining the number of clusters or groups



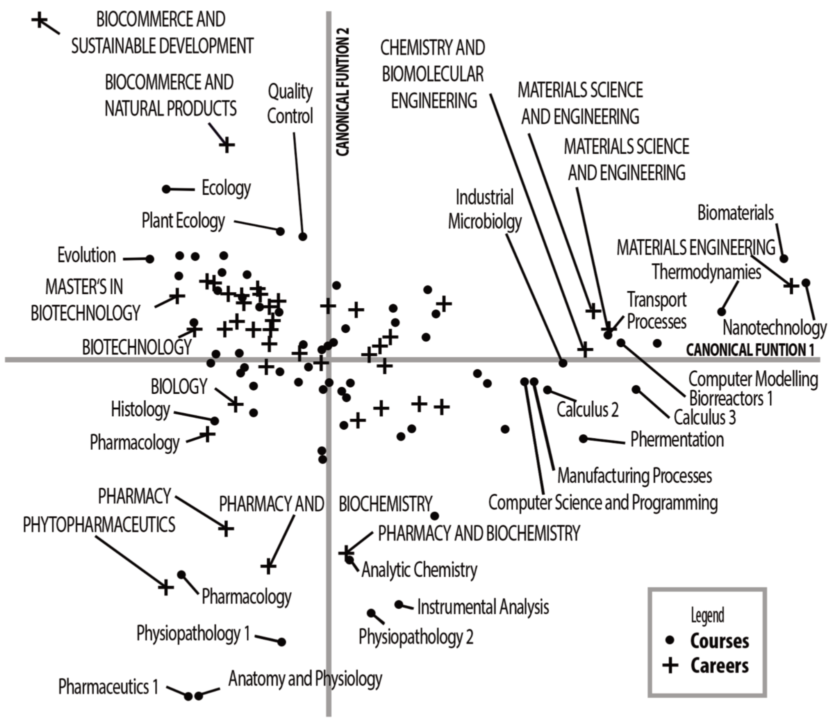
To carry out a CA, we found it convenient to divide the data matrix between courses that were common to all programs, and courses that were unique to specific types of programs. We classified these as Group 1 and Group 4 respectively. We describe this procedure in further detail in the next section. The first CA therefore provided evidence on the overall relationships between those programs and courses that were most common throughout all samples (Figure 3). The second CA estimated how specific academic programs could be distinguished from others by non-common or unique courses (Figure 4). Two different analyses eliminated an intermediate range of programs that could have obscured important relationships or group divisions in the inferred space produced by the analysis and mainly because of clutter when we considered all the data. The goal of the present CA was not to make an exhaustive description of the relative position of each program and corresponding courses but to show how it is possible to infer areas of knowledge in which both programs and courses can be spatially connected and assist in the design of new curricula.

Academic programs associated with Pharmacology occupied a distinct zone in the lower-left region of Figure 3 (i.e., quadrants III and IV of a Cartesian plane). Pharmacological programs were strongly associated with Pharmacology, Pharmaceutics, Analytic Chemistry, Physiopathology, Anatomy and Physiology, and Instrumental Analysis. On the opposite extreme of Figure 3 (upper left of Quadrant II), the two Biocommerce programs remained isolated with considerable distances from other courses and programs, and the closest was Plant Ecology.

The Biocommerce programs had a unique curricular structure, which included low frequencies in courses of Group 1 (see Section 3.4); these properties favored their isolation and distinction in Figure 3. Engineering programs formed another distinct cluster, which was closely associated with courses such as Biomaterials, Industrial Microbiology, Transport Processes, Thermodynamics, Computer Modeling, Bioreactors, Calculus 2 and 3, Fermentation, and Manufacturing Processes. Most of the remaining Biotechnology and Biology programs and courses occurred at the center of Figure 3.

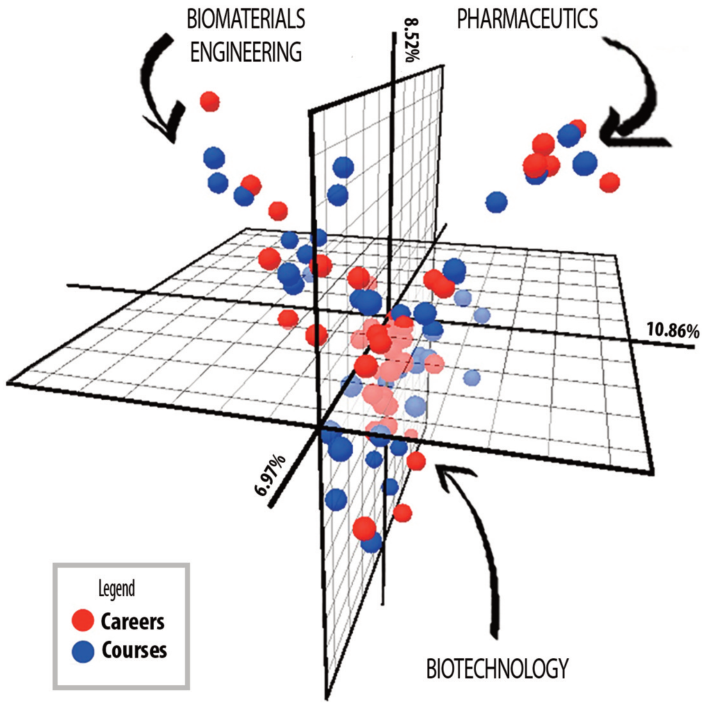
A three-pronged scatter was formed by programs and courses in Figure 4. These three 'prongs' belonged to different areas of knowledge and were constituted by three areas of knowledge that we defined as Pharmaceutics, Biomaterials Engineering, and Biotechnology. Although it was not possible to depict names

Figure 3. A biplot inferred by correspondence analysis and depicting the spatial relationships among 45 careers and their corresponding courses in Group 1 (see Section 3.4). The closer a course was to a career, the stronger the relationship or dependency was between both. Different regions of career curricula were possible to define. The distances between courses and programs represent the lack of statistical independence.



of individual courses and programs due to limitations in the available space in Figure 4, it was clear that there was a definite structure in which particular regions of the inferred space were occupied by specific academic programs and their corresponding courses. The latter may not be fully compatible across academic program curricula.

Figure 4. A biplot inferred by a correspondence analysis of 45 careers and their courses in Group 2 (see Section 3.4). It was possible to establish three distinct areas of knowledge. Percentages indicated on each axis represent the proportion of inertia or lack of independence between careers and courses explained by each canonical vector.

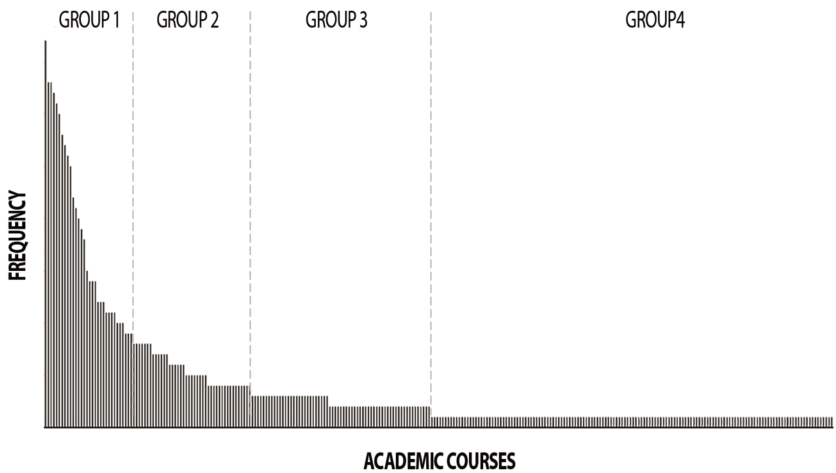


3.4. Frequency distribution of courses

The frequency distribution of 285 courses (histogram), or how common courses were among the 45 academic programs, was too large as a figure to be included for publication but can be requested from the first author. This histogram served as a graphical reference of how important or essential courses were to the program under design. According to the steepness of the slope in the histogram, it was possible to establish four groups of courses. Figure 5 provided a simplified representation of the original histogram. Group 1 included courses that were frequently shared among programs and that should constitute the core curriculum. Group 2 contained courses that, although not as frequent as those in Group 1, could be considered in the periphery of the core curriculum or be present in the concentration part of the curriculum. Group 3 consisted of courses with frequency values of three or two (i.e., only three or two times a course appeared among the 45 analyzed programs). Lastly, Group 4 comprised courses that appeared only once across programs. Courses in these two last groups could exceptionally, or under specific needs, be considered for concentrations or as part of a graduate specialization (e. g. a Master's degree program).

The histogram in Figure 5 (a detailed and expanded version can be requested from the first author) was used as a weighted list of the relevance of available courses that could be included in an academic program curriculum. Given the assigned weight (or frequency value) to courses, the decision about where to place courses in the curriculum framework under design is an informed one. For example, Fundamental Chemistry (also known as General Chemistry) was present in 37 of the 45 analyzed programs, being the single most frequent course. Thus, Fundamental Chemistry could be considered an essential part of the core curriculum and be reasonably placed during the first academic term. The tail of the histogram contained several courses with the lowest weight (i.e., frequency = 1), and it was evident that none could be included in the core curriculum. The courses in the tail of the histogram could serve to design concentration programs within the curriculum. The information conveyed by the histogram provided an objective scale of course value and relevance. As a graphical display, the histogram in Figure 5 could justify the design of a curriculum in quantitative terms.

Figure 5. A histogram that summarizes the presence and relevance of 285 courses in 45 university careers. A more extensive and detailed histogram can be requested from the first author.



4. CONCLUSIONS

According to established theory, the design and innovation of academic curricula are expected to meet several criteria, including but not limited to

1) inclusiveness and valuing of student voice (Brooker y Macdonald, 1999; Idowu, 2004),

2) awareness of the conceptions and beliefs held by teachers on the teaching practice and learning process (Keys, 2005), and

3) gradualness in the development of core scientific ideas in a coherent learning progression (Klymkowsky y Cooper, 2012). The design of new academic curricula should reach a balance between the opposing but complementary facets of academic diversity and scholarly structure (Stark y Lattuca, 1997). Also crucial to the essence of curricula is to imbue it with the necessary components for critical-thinking, complex problem-solving, communication, and interpersonal skills (Diamond, 2008).

Thus, the criteria and characteristics of optimal curricula require practical expertise and theoretical knowledge that could hardly come from displaying the properties of a curricular structure through statistical ordination analyses as in the present study. Accordingly, the goal of the methods we proposed in this study was to provide an initial working structure, based on purely quantitative analytical methods, from where further dialogue and discussion should follow into the design of an optimal program curriculum. The proposed methods provided a measurable scale of course relevance and pertinence, as well as an understanding of similarities and properties in the curricular structure of a group of programs on which we based a new design. As has been shown in this study, having measurable evidence to support a proposal for a program curriculum could be essential when debating or sustaining challenging notions and counterproposals.

The methods and examples provided in this study could be extended into solving other questions related to strategic academic planning, public policies in higher education, academic curricular innovation, and the use of areas of knowledge in interdisciplinary teaching and learning. For example, multiple histograms (such as Figure 5) could be defined for a diverse array of programs and areas of knowledge and could serve for a broader and more insightful study on how knowledge and disciplines are distributed and allocated across universities, regions, societies, and cultures.

Our proposed approach may complement and support curriculum design processes such as those described by Samuel (2002) when transforming teacher education in post-apartheid South Africa. Like Samuel (2002), we believe that during the last ten decades in Ecuador, a process of social development occurred under a rapidly changing environment in higher education, and that this transformation transpired under competing paradigms and educational theories. These processes are often exceedingly complex and bureaucratic, occuring under political forces, and including little or no technical criteria and factual evidence. We believe our method may have greatly assisted the choices made by curriculum designers in the intricate historical setting described by Samuel (2002).

We based our study on a limited sampling protocol that was not entirely random or comprehensive. The best possible alternative for a thorough study will be to sample all available programs of interest worldwide, but this will require considerable effort. A more feasible alternative will be to design an informatics method by which an initial sampling universe can be established, to which it will be possible to apply a randomized sampling protocol that could consider potential confounding factors such as geographic region and socioeconomic and sociocultural aspects where a particular academic program has to be implemented. By delimiting a universe of samples and applying a robust randomized sampling protocol, we will avoid unwanted artifacts such as placing unequal sampling efforts across groups of programs or cultural approaches to education. Most university program curricula are available through the World Wide Web and should be reachable through data mining methods for a robust sampling approach.

The design of program curricula could be approached through quantitative procedures based on multivariate ordination techniques. The matrix formed by the presence and absence of courses across programs (available at the corresponding Data in Brief article) is not limited to the methods proposed herein and could be the source for other innovative approaches into the study of how knowledge integrates into academic programs.

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SHORT BIOS

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