A Proposal Model to Monitor Interdisciplinary Research Projects in Latin American Universities

Rafael Melgarejo and Paulina Cadena

Abstract—**For many years the Latin American university model was aimed at training technicians and professionals. These universities are now trying to develop a pertinent environment for scientific innovation that could contribute to the development of the region. Maybe, interdisciplinary projects are a key part of this environment, if we can agree on the meaning of interdisciplinarity and how to achieve it. This paper proposes a model to monitor interdisciplinarity.**

Index Terms—**Interdisciplinarity, Research projects, collaboration**

I. Introduction

According to UNDP[1], South America has shown a growing development. LATAMC[2] have increased their education index in recent years. However, the gap in technology, research and science continues to grow between developed countries and LATAMC [1].

For developed countries, the gap is due to a problem of modernity [2]. If this is so, the problem is complex and university's role must be intense within its society, provided that Latin American university is interested in being an actor in the development of their region.

In LATAMC, the current university model is oriented to training technicians and professionals, who are necessary for public and private management. The increase in schooling is not an indicative of the development of science and technology in developing countries.

Franklin D. Roosevelt wanted to take advantage of the scientific and technological progress of the war for improvements in common life and sustainable scientific development to ensure a global competitive advantage of the US. Vannevar Bush proposed a self-sufficient scientific knowledge schema for innovation: the creation of a National Research Foundation that coordinates interaction between government, universities, the military, and industry. The Government would fund universities for R&D [3]. Therefore, the university became a key player in the advancement and welfare of its society.

Common interest in living in a better society, A Good Society [4], inspired a model of economic and scientific policy, whose success is achieved if the relationship between actors is trusted. Within this model, a society has three main actors called *The Triple Helix*: 1) the State with its fundamental function: executor of policy; 2) non-governamental Scientific and technological infrastructure: University and research centres; 3) the productive sector incorporating scientific and technological development in its industry, and professionals in the production of services [5].

An effective contribution of universities to social wellbeing has been innovation. The Triple Helix [6] underpins the success of innovation that arises from a relationship between university-industry-government in a knowledge-based economy.

A trustworthy relationship is a process that depends on social, political and cultural factors, which in turn are internal and external to university. To support this process, Latin American universities should demonstrate that their research projects are successful, because they are innovative.

II. Research in University: Origins

A. Educational Models

Some universities are research-oriented. *Universitology* considers three main models of university: Humboldtian (training of researchers), Napoleonic (training of officials, professionals), and Newmanian (training of people).

Wilhem von Humboldt (1767-1835) proposed a university education system for research development. His model was mainly based on ideas of Kant, Schleiermacher, and Fichte. Humboldt's model was considered elitist by Napoleon. The French Republic established a university model for ordinary people in order to train public servants. Cardinal John Henry Newman (1801-1890) proposed a University for citizens' ethics training in liberal arts and sciences. In any model of university, its outcomes (professional or research) are part of society.

III. Patents and Publishing

The effective contribution of universities to the advancement of science and technology is through research projects that generate new discoveries, i.e. innovation. These discoveries

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[1] United Nations Development Programme

[2] LATin AMerican Countries

should be disclosed from Universities[8], towards social wellbeing.

A way to measure innovation is by the number of patents registered [9]. USA has 56% of the total patents of the World [10]. Since the *Bayh–Dole Act*[3] or Patent and Trademark Law Amendments Act, universities in USA have competed between them in order to achieve more patents.

In recent years, competition between universities of developed countries has changed rotation, perhaps because the global ranking of universities no longer takes into account the number of patents [11]. At present, competitiveness goes to international collaborations and coauthorships between universities for publishing [12]. There is a growth in international coauthored papers for selected countries and the proportion of national output that this represents. Russia has the highest number of collaborative papers published per year, followed by the United Kingdom, Germany and France [13].

IV. Research in LATAM Universities

Taking into account the research outcome of LATAMC, it seems that the Humboldtian model has not been incorporated in their universities, because these countries have only 0.2% of world patents. Brazil and Mexico registered the highest number of patents until 2013 in the region.

TABLE 1.
TOTAL NUMBER OF PATENTS PER LATAMC [10]

COUNTRY	#PATNT	COUNTRY	#PATNT
Brazil	3037	Trinidad Tobago	84
Mexico	3037	Guatemala	71
Argentina	1526	Panama	70
Puerto Rico	1007	Ecuador	62
Venezuela	774	Bolivia	54
Chile	460	Dominican R	46
Colombia	292	El Salvador	38
Costa Rica	148	Honduras	33
Peru	141	Haiti	29
Cuba	120	Nicaragua	22
Uruguay	93	Paraguay	11

Since 2000 a substantial increase has been observed in the patenting of universities from: Brazil, Argentina, Chile, and Uruguay. The registered patents between 2000 and 2013 were twice as many as all those registered until 2000 [10]. However, the vast majority of patents in these countries are ergistered in the private sector and by non-residents. 11.8% of the granted patents in LATAMC are by residents [14]. The *Invention Coefficient* refers to patents filed by residents per 100,000 .

TABLE 2.
INVENTION COEFFICIENT IN US & LATAMC [14]

COUNTRY	InvCoef	COUNTRY	InvCoef
United States	41.90	Costa Rica	0.33
Brazil	2.54	Colombia	0.27
Chile	2.25	Bolivia	0.24
Argentina	2.16	Ecuador	0.20
Uruguay	2.13	Guatemala	0.20
Cuba	0.99	Paraguay	0.20
Venezuela	0.77	Jamaica	0.17
Portugal	0.62	Peru	0.13
Mexico	0.61	Honduras	0.12
Panama	0.55	Nicaragua	0.08
El Salvador	0.41	Dominican R	0.00
Trinidad Tobago	0.34	Haiti	0.00

The number of patents of Latin American universities and their *invention coefficient*[4] [14] confirms the gap with universities in developed countries.

Rotation in competitiveness affects Latin American universities, which achieved a three-fold increase in their standard domestic publication impact through collaboration with others [13]. Despite rotation in competitiveness, to the naked eye it is noticeable that Latin American countries with a higher invention coefficient are also countries with the highest rate of scientific international collaboration among universities [15].

TABLE 3.
IMPACT ACCRUED BY LATIN AMERICAN COUNTRIES DUE TO A COLLABORATION WITH A UNIVERSITY FROM A DEVELOPED COUNTRY (MINIMUM OF 1,000 PAPERS PUBLISHED BY EACH COUNTRY IN 2008 IN COLLABORATION WITH) [13]

	Argentina	Brazil	Mexico
UK	3.2		
Australia		4.5	
Canada		3.1	
Japan		3.7	
Netherlands		3.9	
Germany			3.1
Italy			3.4

Nowadays, research is implemented as a function within the administrative structure of universities in LATAM. In its structure, an R&D[5] department should promote research and allow managing various projects from different faculties or academic units within a university. In practice, this department becomes a body that approves, based on an overall budget, specialized research projects presented by different faculties or degrees [16]. In this isolated environment, with the right leadership only close innovation is expected; in other words, a researcher must have a brilliant idea within his/her area of expertise and invent something new for the world working in an isolated laboratory.

[3] Bayh–Dole Act permits (a university) to elect to pursue ownership of an invention

[4] Patents filed per 100,000 residents

[5] Research and Development

In this panorama, the outcome of the university model in LATAMC leads to scarce patents and lack of collaboration. It seems that the Latin American university model is a mixture between the Napoleonic and Newmanian models.

V. Collaboration for Innovation at Universities

Worldwide

Collaboration can be inside or outside the boundaries of the university. Inside: the concurrence of several disciplines within an investigation. Outside: among universities and/or with government and private sector participation.

For the last years, collaborative initiatives between universities and the private sector have come from the paradigm Open Innovation, OI, that considers internal an external flows of knowledge to and from firms that contribute to innovation [17]. State funding is also important.

An Innovation Cluster (IC) is the explicit collaboration between especific firms and some universities, within a geographical concentration, and with a high degree of specialization [18]. Innovation Clusters have had a high degree of innovation. US, Sweden, Finland, South Corea, and Japan had the highest R&D intensity through clusters among them. In LATAMC Mexico, Brazil, and Chile appear with a low degree of innovation through clusters [19], among universities around the world.

Governments may foster innovation-led clusters, but it is a long-term effort [20]. The private sector wants short-term results, i.e. products that could be offered to markets. The collaborative efforts can then be lowered.

LATAMC

Geographical concentration and high degree of specialization may also limit the role of Latin American universities.

In Latinamerica, collaboration between disciplines inside the university is a great effort [21]. Some collaborative efforts have been made inside universities in order to do a specific consultant work for companies or for the government in the service area [16]. These efforts constitute a multidisciplinary approach within universities [22].

However, multi-disciplinarity does not lead to innovation directly. Other kinds of effort have involved the design of interdisciplinary courses trying to improve innovation outcomes, or to do this faster [23]. These courses or training within universities have occurred in response to the isolation caused by the study of formal education disciplines, which does not help much to find new solutions or creativity to solve complex problems [24].

Plato's Academy and Humboldt’s Integrative Theory of Education seem to be updated in the proposed *cooperative studies* [25] and interdisciplinary research in universities.

VI. What is Interdisciplinarity?

The Academia many times uses the term interdisciplinary, e.g.:

a. Conferences and local meetings across disciplines tagged as interdisciplinary.
b. Courses inside universities [26].
c. Some web-based educational offers evoke Interdisciplinarity [27].
d. Proposals to measure perceptions of interdisciplinary education, which are still being tested [28].
e. Apparently, diffusion and penetration in using new information and communication technologies allows Interdisciplinarity in an easy way. Technology provides an adequate environment for synergy in multidisciplinary work [29].
f. In Latin America, interdisciplinarity looks like a new professional framework within engineering [30], and so does the combination of engineering and education [31] in order to solve engineering problems [32].
g. Efforts to develop interdisciplinarity with collaboration between universities [33].
h. In 2013 in Brazil, the "Capes da Qualis" system endorsed 8985 journals as interdisciplinary [34].

Collaboration between various disciplines and integration of knowledge of various sciences to solve common problems leads to confusion or a myth in the understanding of the meaning of interdisciplinarity [35].

Interdisciplinarity is like a synoecism (disciplines dwelling together in a research project) [36].

Interdisciplinarity can be a state in the development of integration of disciplines, when collaboration meets interactions that allow the development of the disciplines involved, reaching a reciprocal evolution of all disciplines [37], or at least in one of them.

One of the outcomes of research in interdisciplinary terms is a re-organization of different disciplines through a dialogue of mutual exchange that overcomes the limitations of scientific progress [21].

Research projects for innovation are involved in a middle and long term processes. These processes begin with an interaction of knowledge fields revealing three kinds of collaboration:

a. <u>Multidisciplinary:</u> collaboration between disciplines involved in efforts to resolve a specific problem.
b. <u>Interdisciplinary</u> to solve *complex problems* or to create *revolutionary science* [38] beyond *the Scientific Method* [39]:
c. <u>Transdisciplinary</u>: remove faculties as promoters of research, and create ad-hoc dynamic research units for research projects.

Therefore, *interdisciplinarity is the evolution of one or more disciplines, or the emergence of a new one, because of their interaction within a research project that leads to innovation.*

This evolution of science or disciplines constitutes a generation of new knowledge within the university, or the outcome of an Open Innovation process. Success is tangible with the invention of a new product that can be patented and industrialized. Interdisciplinarity seems to be a key to innovation [40]. However, even if there is not a new product, within academia interdisciplinarity is important for the progress of science. Interdisciplinarity is a key source of ontological progress of scientific disciplines.

VII. PROPOSAL

The evolution of any discipline constitutes a reorganization of its epistemological basis, or maybe the emergence of new concepts and disciplines/sub-disciplines.

As a semiotic problem, one single concept could have different meanings for each discipline involved in a project. According to the pragmatic branch of semiotics, it is also possible that the same concept within the same discipline has different meanings, depending on the language or country, which means differences among colleagues from the same discipline but from different universities of origin. Therefore, the conceptual basis for each discipline is needed.

This proposal has three aims:

1. To demonstrate interdisciplinarity: to indicate concepts that have changed from the start to the end of a collaborative project.
2. To track the collaboration process among disciplines, the proposal is to perform a taxonomy of the collaborating disciplines using Web ontology[6] [41]. Considering disciplines and sub-disciplines as entities and concepts as classes, using OWL[7] we can obtain a knowledge representation at the beginning of the project. At every milestone of the project, this representation can change. Changes are evidence of interdisciplinarity,
3. Although interdisciplinarity is not achieved, the ontology representation would help to develop a knowledge base of Science. Far beyond, if this knowledge base is in the Web, the hierarchical outline of science[8] may improve.

There are some efforts of lexical databases or semantic networks of concepts like BabelNet[9], FrameNet[10], and WorldNet[11]. These efforts respect the concepts within each discipline, and some of them are limited to the English-speaking culture. The proposed model can be a tool to dynamically change the ontology of science from the interdisciplinary work of collaborative networks inside or outside universities.

This proposal constitutes a top-down construction of ontologies, from the Upper-Level where general concepts are supposed to be the same across disciplines. Concepts begin to specialize within disciplines. Through an interdisciplinary approach, the specificities of the concepts inside disciplines may find similarities or could lead to their evolution.

In this approach, Latin-American universities could easily be involved, especially for semiotic considerations that allow innovation through interdisciplinarity.

[6] World Wide Web Consortium (W3C) efforts in the Semantic Web (Ontology Web) are oriented to develop ontologies from low-level, that means from digital resources around the world [41].

[7] Web Ontology Language.

[8] Organization of Science: methods, branches, disciplines, sub-disciplines, concepts.

[9] http://babelnet.org/

[10]https://framenet.icsi.berkeley.edu/fndrupal/

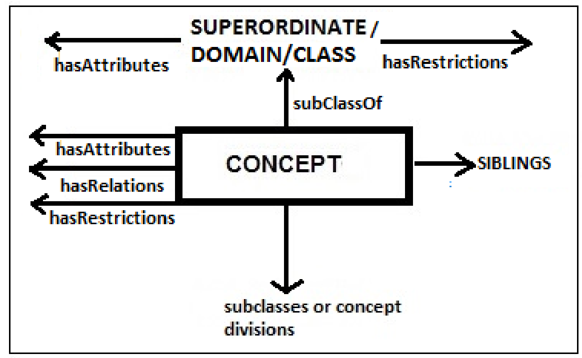
[11] http://wordnet.princeton.edu/

A Model to Monitor Interdisciplinary

To track a collaboration process among disciplines within a research project, the model proposes the following steps:

1. For every discipline/sub-discipline involved building a glossary (clavis/conceptual basis) of the key concepts that seem to be used within the project.
2. Within each conceptual basis, doing an ontology schema for each concept [42]. For upper concepts, the Superordinate or Domain must be the discipline or sub-discipline.

TABLE 4.
CONCEPT ONTOLOGY SCHEMA[12]



3. With *OWL* developing an *RDF Schema*[13] according to the Concept Ontology Schema, establishing the relationship of the concepts contended in the conceptual basis. Considering a discipline or a sub-discipline as a domain:
   a. Within the same discipline or sub-discipline, connect concepts at their domain level.
   b. Connect concepts considering siblings.
   c. Define and connect subclasses.
   d. Connect domains according to Branches of Science division (scientific fields or scientific disciplines).
4. Creating a Committee of Experts of the knowledge areas involved. Experts can be located around the world and use collaborative tools [44] to communicate. The Committee should address, map and analyse concepts:
   a. When possible (if a concept has the same meaning: attributes, relations and restrictions) connect concepts across disciplines.
   b. The same as "a" at subclass level and siblings among disciplines.
   c. Be aware if in a serendipity moment a possible change of a concept emerges.
5. Once a possible change is addressed, experts locate disciplines and sub-disciplines related to the concept. Because a change can modify the relationship with other concepts, it is imperative to analyse the relations of the concept within its own discipline/sub-discipline, and contrast it with the same concept defined in other

[12] Adapted from [46] and [43].

[13] Resource Description Framework Schema is a set of classes to represent knowledge through ontologies [43].

disciplines involved in the project. To carry out this analysis, experts should locate the concept in matrices. Each matrix helps to map the relation of the concept between two disciplines or sub-disciplines. To do this, it should be taken into account that:

a. Maybe a concept has a different ontology within a discipline or sub-discipline, according to the knowledge area, or the research line.
b. It is necessary to organize the level of interaction of disciplines in binary form (D: Discipline; SD: Sub-discipline; KA: Knowledge Area; RL: Research Line). The following hierarchy is considered:
    i. RL is a subset of KA
    ii. KA is a subset of SD
    iii. SD is as subset of D

TABLE 5.
CROSSING MATRIX BETWEEN RESEARCH LINES [45]

			DISCIPLINE 1 / SUB-DISCIPLINE 1.1					
			K.Á. 1.1			**K.Á. 1.2**		
			R.L. 1.1.1.	R.L. 1.1.2	R.L. 1.1.3	R.L. 1.2.1	R.L. 1.2.2.	R.L. 1.2.3.
DISCIPLINE 2 / SUB-DISCIPLINE 2.1	**K.Á. 2.1.**	R.L. 2.1.1.						
		R.L. 2.1.2.						
		R.L. 2.1.3						
	K.Á. 2.2	R.L. 2.2.1						
		R.L. 2.2.2.						
		R.L. 2.2.3.						

c. It is necessary to create as many matrices as combinations of interacting disciplines or sub-disciplines related to the same concept: one matrix for two disciplines, three matrices for 3 disciplines, six matrices for 4 disciplines. The number of matrices is a combination of n things taken 2 by 2 regardless of the order. The formula to calculate the number of tables / matrices is:

$$\frac{n!}{(n-2)!} * \frac{1}{2!}$$

6. In the crossing points write down the identified concept, and its ontology, that may change during the development of the research project.
7. With the change of the concept and/or the mapping relations, in the RDF schema redefine the ontology of the concept and establish its relationship with other disciplines or express their semantic similarity between disciplines.
8. The concepts of each discipline can remain in a Domain Ontology. An interdisciplinary process may try to push a concept to an Upper Ontology, a commonly-agreed definition across disciplines.
9. Another possibility of a successful interdisciplinary project is to redefine the Domain Ontology within each discipline or the emergence of a new discipline with its own ontology.
10. Set milestones in the project's timetable to review possible concept changes using the RDF schema.
11. At the end, interdisciplinarity is achieved if:
    a. One or more concepts are transformed, since they were conceived differently in each discipline at the beginning of the research.
    b. A new common concept for several disciplines emerges.
    c. An agreement among disciplines is reached about the meaning of a concept that was defined differently at the beginning of the project by the disciplines involved.
    d. A new discipline or sub-discipline emerges.
12. Publish the final version of the RDF Schema into the Web. Open access suggested.
13. Universities should co-administer a collaborative site that dynamically performs improvements of the hierarchical outline of science using ontologies.

The model should be tested with interdisciplinary projects. Testing can open new frontiers of Science. Perhaps an ontology of Science could shape a dynamic graph instead of a pyramid, showing a permanent innovation through collaboration among researchers of different universities.

VIII. CONCLUSIONS

Universities in LATAMC can take the initiative to promote trustworthy relationships, demonstrating success in their interdisciplinary projects. Interdisciplinarity is an Open Innovation process achieved with the concurrence of several disciplines. Latin American universities would be actors in this process of innovation, because they are sources of pragmatic knowledge.

Collaboration between Latin American universities and universities of developed countries is needed to reach agreements and knowledge to establish the pragmatic differences among them that can enrich collaboration and innovation.

The most important outcome of a successful interdisciplinary project is achieved if the Domain Ontology of a discipline is redefined or if a new discipline with its own ontology emerges.

The proposed model allows showing evolution of the science fields that have interacted within the investigation. Evolution of disciplines is the aim of interdisciplinarity.

International collaboration increases scientific activity, resulting in the expansion of Science.

The hierarchical organization of disciplines changes dynamically according to the development of science and innovation. Possibly the organization of science should be like a graph instead of a static hierarchy, a new vision of the Outline of Science.

Collaboration between universities can create a high-level ontology of Science from interdisciplinarity.

The proposal model is innovative, and it should be tested within a collaborative research project among universities, trying to achieve interdisciplinarity.

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