

KNOWLEDGE PRODUCED IN NANOSCIENCE AND THE RESULTING INTERNATIONALIZATION: ANALYSIS OF THE NETWORK THEORY¹
CONHECIMENTO PRODUZIDO NA NANOCIÊNCIA E INTERNACIONALIZAÇÃO RESULTANTE: ANÁLISE DA TEORIA DA REDE

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ABSTRACT

Internationalization is already widespread and intertwined with the business market process. Within this context, the generation of knowledge and the creation of collaborative networks becomes a factor of competitiveness for institutions of higher education in the academic and research perspective. The scenario that knowledge becomes accessible worldwide is through publication in periodicals and is one process to evaluate the internationalization including tools that allow the verification. The validation of these networks, resulting from the citation of this knowledge, can potentiate future actions to bring researchers closer to their network. The present study focuses on the interdisciplinary stricto sensu postgraduate Program in Nanoscience of the “Centro Universitário Franciscano”, seeking to build the internationalization network of knowledge through the systematic analysis of publications that cite the works published by the Program. It was possible to evaluate that the issues stemming from citation of the knowledge of the Program in delimited axes, which allows the search to catalyze efforts in the expansion of internationalization. In addition, approach the network formed in a passive way by the observation of the publications, and to turn them into active collaboration networks, increasing the potential of international insertion.

Keywords: nanoscience and nanotechnology, collaboration networks, innovation, scientometrics.

RESUMO

A internacionalização já está difundida e interligada ao processo do mercado empresarial. Dentro deste contexto, a geração de conhecimento e a constituição de redes de colaboração torna-se fator de competitividade para instituições de ensino superior na perspectiva acadêmica e de pesquisa. O cenário que o conhecimento se torna acessível mundialmente por meio da publicação em periódicos de referência cabe ao processo de avaliação da internacionalização incluir ferramentas que possibilitem a verificação e principalmente a validação destas redes decorrentes da citação deste conhecimento para potencializar futuras ações para aproximar pesquisadores de sua concentração de estudos internacionais. Este estudo tem como foco o Programa interdisciplinar de pós-graduação stricto sensu em Nanociências do Centro Universitário Franciscano buscando construir a rede de internacionalização do conhecimento por meio da análise sistemática das publicações que citam o conhecimento publicados pelo Programa. Foi possível avaliar que os temas decorrentes de citação do conhecimento do Programa em eixos delimitados, o que permite a busca por catalisar esforços na ampliação da internacionalização, bem como aproximar a rede formada de forma

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passiva pela observação das publicações, e permitir transformá-las em redes de colaboração ativas, ampliando o potencial de inserção internacional.

Palavras-chave: *nanociências e nanotecnologia, redes de colaboração, inovação, cientometria.*

INTRODUCTION

At the end of the twentieth century, nanoscience and nanotechnology achieved a vertiginous growth, consolidating as a new area of knowledge and, thus, reinforcing the promise of revolution in science and technology, as occurred in the industrial revolution of the eighteenth century.

The nanostructured materials significantly altered the physical and chemical characteristics, which can contribute to the improvement of the development of new applications, with potential of industrial application with low temperature development and processed of different modes and forms (RESCH; FARINA, 2015).

Considering that human knowledge and talent can be, today, one of the main competitive differentials for different organizations, the university, in a significant way, contributes to the generation and transmission of knowledge, enhancing the individual talent. Thus, to observe the evolution of the generated knowledge and to understand how to potentiate its diffusion becomes important in the academic perspective.

The search for intelligence about the internationalization of education starts from the understanding that the process of globalization and the dissolution of physical boundaries is a natural consequence. According to Audy and Morosini (2007) there is a confluence of forces that work directly on the dynamics of universities, among the main ones, at present the internationalization process stands out.

The development of research that identifies the exploration of scientific works in the segments of Nanoscience is necessary in order to diagnose possible gaps in the decision-making process that demand attention and future development. In this sense, the problem of this study is the identification of the networks generated by the knowledge developed of a graduate Program in Nanoscience⁵.

This work aims to identify the research segments, associated to the themes related with Nanoscience and the networks of authors resulting from the dissemination of this knowledge. The identification of these segments will allow the observation of connections that, in some way, translate a road of evaluating the internationalization of knowledge resulting from the publications of the postgraduate Program in Nanoscience of the “*Centro Universitário Franciscano*” generated through articles based on periodicals.

The process of constitution of the Program in Nanoscience of the “*Centro Universitário Franciscano*” began with the approval of the Master level and its implementation in March 2007, in De-

⁵<<http://www.unifra.br/site/pagina/conteudo/53>>.

cember 2011. The approval of the Doctoral level representing an important fact for the “*Centro Universitário Franciscano*” in relation to the its development directed to *stricto sensu* and research. This fact also contributed to the central region of the state of Rio Grande do Sul as the interdisciplinary activities of teaching and research provided in the Nanoscience area.

Thus, the objectives of the Program are: to qualify human resources, through an interdisciplinary training, to act in teaching and research activities; contribute to regional and national development in the Nanoscience area; produce knowledge and promote the dissemination and consolidation of Nanoscience through the development of research that enables technological innovations; encourage exchanges and foster cooperation with other higher education and research institutions, as well as public/private sector companies (UNIFRA, 2017).

The Program has two principal research lines: i) development and characterization of bioactive and nanostructured systems and ii) modeling and simulation of biosystems and nanomaterials. These lines allow the audience to be obtained from areas such as Licentiate and/or Bachelor in: Biomedicine, Computer Science, Pharmacy, Physics, Mathematics, Chemistry, Information Systems and other related areas.

It is observed that one of the main objectives of the Nanoscience course is the internationalization of the research through formation of human resources and high-level research. Then, starting from a theoretical reflection through the exploratory bibliographic research by sampling taking quantitative data of the scientific knowledge generated on the Nanoscience course. It was applied the bibliometric analysis on the scientific production of the Scopus platform generated by researchers linked to the Program, their contribution in the development of world knowledge and the constitution of the international research networks.

One of the concerns of the scientific community, especially in emerging countries, currently surrounds the topic of internationalization of scientific production, so the importance of internationalization in the flow of generation, diffusion and employment of scientific knowledge demands the establishment of new parameter to follow its evolution (PINTO; CUNHA, 2008; SANTIN; VANZ; STUMPF, 2016).

Among the parameters for the evaluation of the internationalization of scientific production, Santin, Vanz and Stumpf (2016) present a proposal of three dimensions:

- a. International diffusion - production and publication in international journals;
- b. Co-authoring - participation of author from different countries in publications;
- c. International impact - citation received from other international publications.

The international diffusion of knowledge has revealed greater effectiveness in biological, exact and earth sciences areas (SANTIN; VANZ; STUMPF, 2016). In this context, in addition to working the potential of other areas in the international insertion, it is necessary to ask questions related to language as a central element for the effective distribution of knowledge, since currently English has the prerogative of an effective international science (ROYAL SOCIETY, 2011). The in-

ternational collaboration aims the development through the knowledge sharing among several countries, searching for the best solution of common problems.

In this environment, we usually find the production of knowledge with the greatest impact on citations, making the word “research” more effective (GERSHENSON; ADAMS, 2013).

In the context of international impact, the characteristics are based on the use of information presented in new research, and is evaluated by the performance of the publication in citations received in later studies. In this scenario, the impact means to aggregate ideas from science to global knowledge (MCMANUS; NOBRE, 2017; SANTIN; VANZ; STUMPF, 2016; ROYAL SOCIETY, 2011)

To visualize the potential of internationalization of knowledge, it demands the use of techniques that allow an extended observation in relation to the impact of the publications, in this way, the analysis based on the creation of networks appears as one of the evaluation possibilities.

By observing the organizational environment by a competitive breadth, the need for cooperation between authors, teachers and Programs focuses on the search for knowledge enhancement. Thus, the creation of active or passive networks has presented potential for internationalization in different segments and areas (CRUZ, 2015).

Contributing to this vision, Silva, Barbosa and Duarte (2012) emphasize that knowledge related to networks has a strong relationship with the interdisciplinary area of knowledge. Within this context, highlighted by the work of Ferreira and Filho (2010), the network can be constituted in three formats: i) the centralized one that presents a star format counting with centralized node; ii) the decentralized where several groups of nodes have a specific center, there is no center common to all, but interconnected with each other; iii) and distributed, where there is a distribution and similarity of connections between the nodes, not presenting a reference center.

According to Postiglione and Altbach (2013) the fundamental actor to promote the diffusion of knowledge is in the teaching staff and, without their interaction in the process, the internationalization efforts tend to be fruitless. Due to this fact, the teacher or research has the key element to the internationalization, once the network is one of the instruments for its accomplishment. The contacts and partnerships established with international actors make this professional differentiated for the market (GUIMARÃES; GALVÃO, 2015).

In this way, when looking at the cooperation networks, it is observed the research segments addressed in the Program, through the interconnection links between the authors and their study themes provided in the light of the objective outlined for this study and allowing a different look of the internationalization process developed in the Program.

MATERIAL AND METHODS

As a data collection strategy, for reasons of accessibility to information, the *Scopus*⁶ database, produced by Elsevier since 2004, has been used, which offers a wide coverage of the scientific and technical literature published since the 19th century in several areas of knowledge (ELSEVIER, 2015). The systematic review is divided into 3 phases as described below. The data collection was performed in the temporal cut of April 22, 2017.

Phase 1 presents the search in the Scopus database for the keyword “NANO *”, generating 1,417,490 records, after the filter was applied to articles of origin in Brazil, generating 18,565 records and following the delimitation of affiliation for articles originating in the “*Centro Universitário Franciscano*” with 116 records.

Based on the results found at the end of Phase 1, Phase 2 sought to identify articles that cited related articles in the previous phase, in which 1,365 records were highlighted. Thus, after this verification was applied the exclusion filter of author or coauthor associated with the Program of Nanosciences from “*Centro Universitário Franciscano*” leaving 1,286 records, and sequentially the exclusion of articles generated by researchers in Brazil having 1,035 records.

Phase 3 sought to delimit the research, so Phase 3.1 adds to the filter the restriction to the country “China”, because it was highlighted in the volume of scientific production in the key word “NANO *” (DALLA NORA; FAGAN, 2016).

At the conclusion of this step, Phase 3.2 returns to the base data of Phase 2 and applies the “United States” country filter due to being the second world expression in volume of scientific production resulting from the key word in the world context (DALLA NORA et al., 2016).

The documents identified in Phase 3, the systematic review of the connection network, were evaluated in relation to the connection of the researchers and their relationship with the knowledge production of the “*Centro Universitário Franciscano*”. Thus seeking to build the network of relations resulting from this relationship with perspective in words and actors.

The construction of the network in this work was focused on the network of citations. In this way, with the support of free software Iramuteq®. From it will be applied the hierarchical classification description (CHD) method proposed by Reinert (1990). This methodology uses the textual corpus for the dimensioning of text segments or units of elementary context (UCE), classified according to the vocabularies of higher frequency and chi-square values highlighted in the class. The analysis of data and information will be consolidated and presented in the form of distribution charts. (FERRARA; FRIANT, 2016; KAMI et al., 2016; ZOUHRI et al., 2016)

The network was developed with the support of the Program created by Eck and Waltman, (2010) under the name VOSviewer, available for free use that enables the creation of maps and net-

⁶<www.scopus.com>

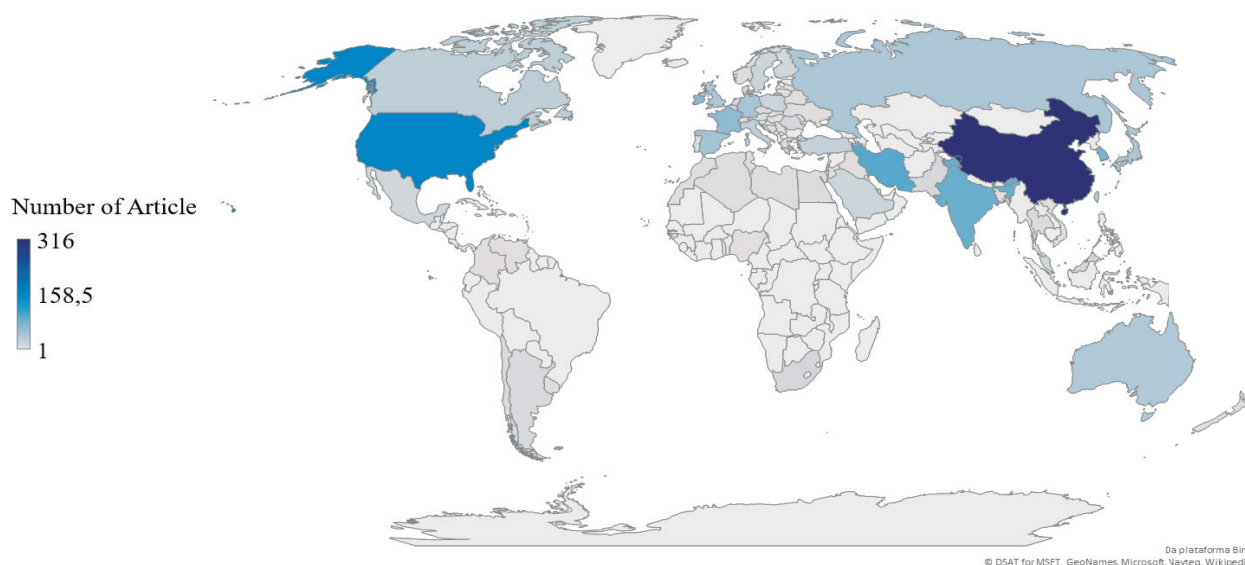
works using mapping and grouping techniques. The use of this software is basically for bibliometric analysis when we have a large volume of data to be treated, having as a differential, the ability to create graphical representations of the data, with the creation of word maps a field formation, based on network of co-occurrence from the title and summary of scientific documents, proposed by this study. The use of this system is due to its wide functionality and application in several scientific works, especially on the use of genetic resources in the field of genetic engineering. (ARORA et al., 2013; BARTH; HAUSTEIN; SCHEIDT, 2014; CALDEIRA et al., 2014; ECK; WALTMAN, 2010; LEYDESDORFF; RAFOLS; CHEN, 2013; WAAIJER et al., 2011)

RESULTS AND DISCUSSION

The analysis of the results was based on the observation of the scope of knowledge generated by the Nanoscience Postgraduate Program of the “*Centro Universitário Franciscano*”. It was possible to verify the distribution of the countries that cite articles published by researchers associated with the Program. The country of origin is China, with 316 citation the Program works, followed by the United States with 156 papers that cite the publications. The data are shown in figure 1.

In-depth analysis of the topics of interest demonstrated by the citations of the knowledge generated and published, the analysis starts from the systematic publication of the postgraduate Program in Nanoscience of the “*Centro Universitário Franciscano*”, presented in figure 2, where the X and Y axes represent the force or repulsion between the class of words, by the technique of CHD. By the method of Reinert (1990), each class were identified by the variation in color and in this case generating five (5) classes of concentration of the subjects.

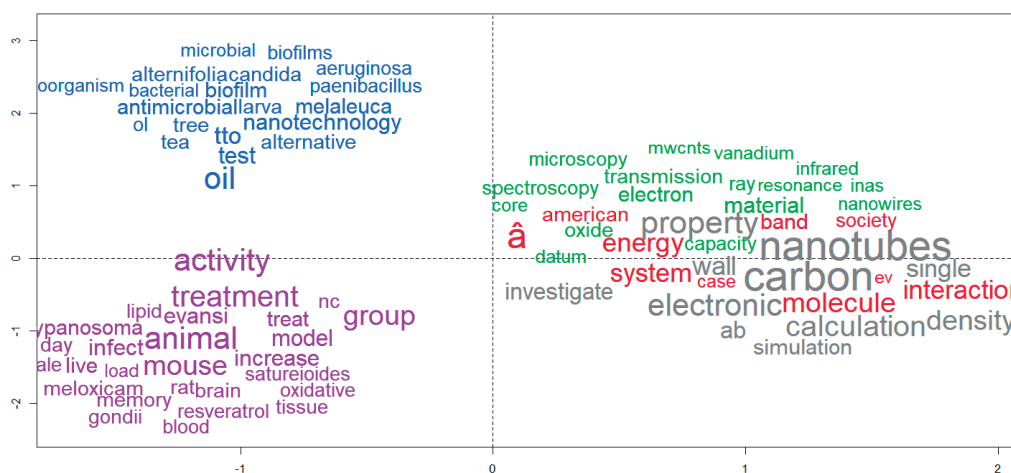
Figure 1 - Global distribution of articles that cite the work of the Nanoscience Program by country of origin.



Source: author's construction.

The positioning of these words was carried out by axes of multivariate analysis, the size of each word stems from the frequency of occurrences and their connections. This being the phase 1 of the methodological proposal that describes the data of the 116 articles.

Figure 2 - Distribution of classes of words by occurrence and connections of the works of the Nanoscience Program.



Source: author's construction.

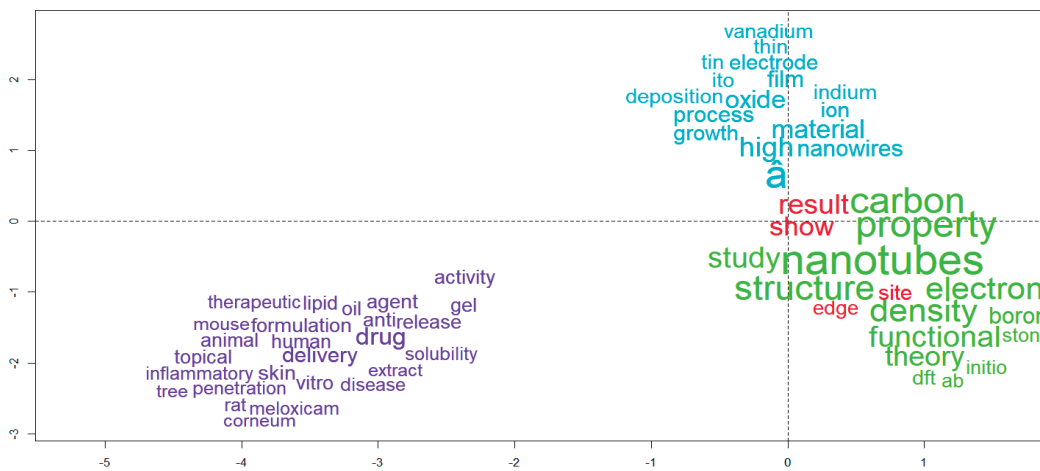
Among the five (5) classes of concentration of “words”, considering a relation of proximity between the groups: gray with the main words “nanotubes” and “carbon”; red with the words “Å” (Ångström) and “molecule”; and green with the words “material” and “electron”. The class highlighted by purple color with low relation with the others, having as main words “mouse” and “animal”. The blue class with highlight the words “oil” and “nanoparticles”.

The CHD distribution of the relationship classes of the concepts is presented in figure 2, where the X and Y axes represent the force or repulsion between the class of words, in this phase of the study it was possible to evaluate the constitution of 4 classes of grouping, being evaluated the proximity of concepts to the green class that was highlighted the words “nanotubes” and “property”; The blue class with highlights of the words of relevance in the graph for “Å” (Ångström) and “material”; and the red class with less prominence counting on the representation of the word “result” and “show”.

With a poor adherence to the other classes, the purple presented in addition, a lower influence of the terms, observed in figure 3 where the X and Y axes represent the force or repulsion between the class of words, by the proportion of words, being prominent for “drug” and “delivery”.

The analysis of Phase 3 was highlighted in two segments, figure 4, where the X and Y axes represent the force or repulsion between the class of words, describes the classes derived from the works that cite the knowledge published by the Nanoscience Program at China, the country of origin of the article.

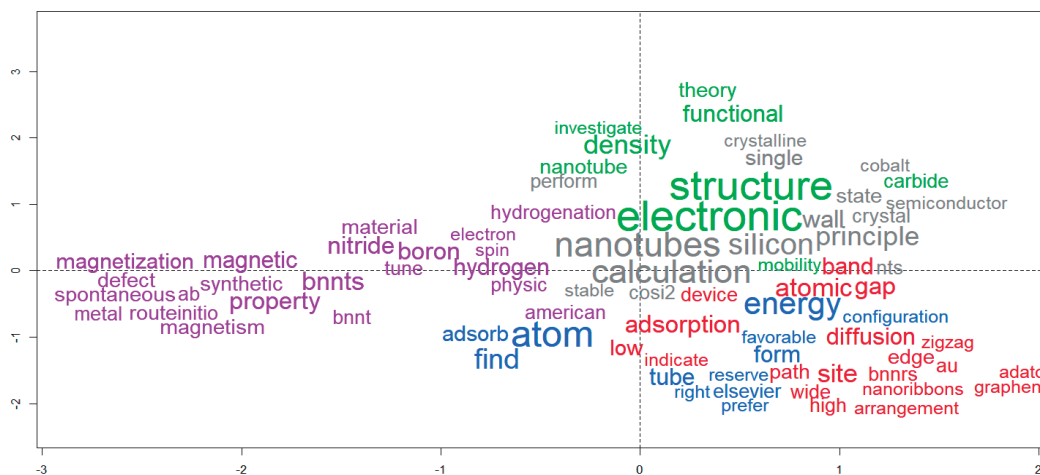
Figure 3 - Distribution of classes of words by occurrence and connections of the works that cite the publications.



Source: author's construction.

It was possible to identify the formation of five (5) classes of grouping of the studies, in this scenario having a greater proximity between all the classes comparing the figures 2 and 3. Thus, in the green class the highlight was with the words “electronic” and “structure”. The blue class with highlight for “atom” and “energy”. In the gray class for “calculation” and “surface”. The blue class was highlighted with the terms “atom” and “energy”. In red class with prominence for “atomic” and “adsorption”. The purple class presented a small displacement and distribution of keywords with “boron” and “bnnts” (boron nitride nanotubes).

Figure 4 - Distribution of classes of words by occurrence and connections of works of origin in the country of China.

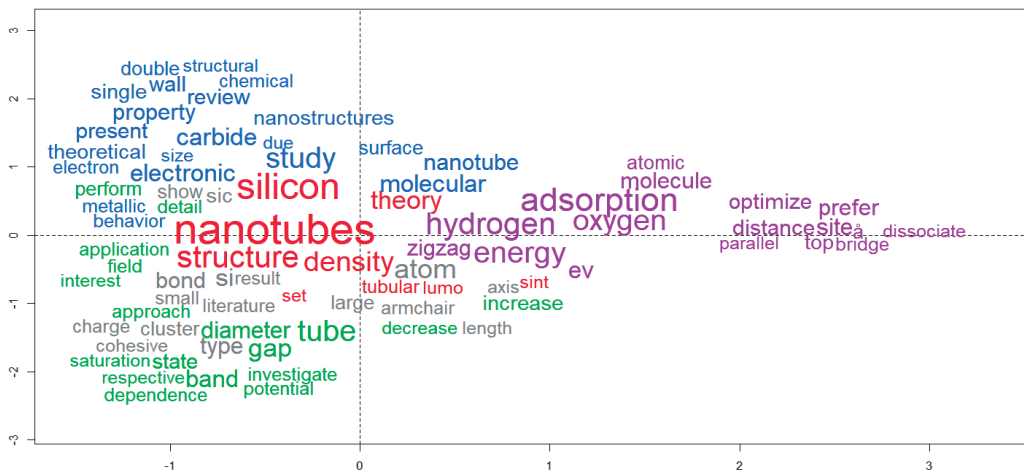


Source: author's construction.

The data analysis segment of the United States are presented in figure 5 with the formation of five (5) classes of the studies and with a similar structure of the data presented in figure 4, where the X and Y axes represent the force or repulsion between the class of words. The red class with prominence for the words “nanotube” and “silicon”, the purple class with the words “adsorption” and “hydrogen”,

in the blue class there was highlight for “study” and “molecular”, already for the green class the highlight was with “tube” and “gap”. Since the gray class in this scenario presented a weak relation, a fact observed by the little prominence of the words, and presenting as main “atom” and “type” themes.

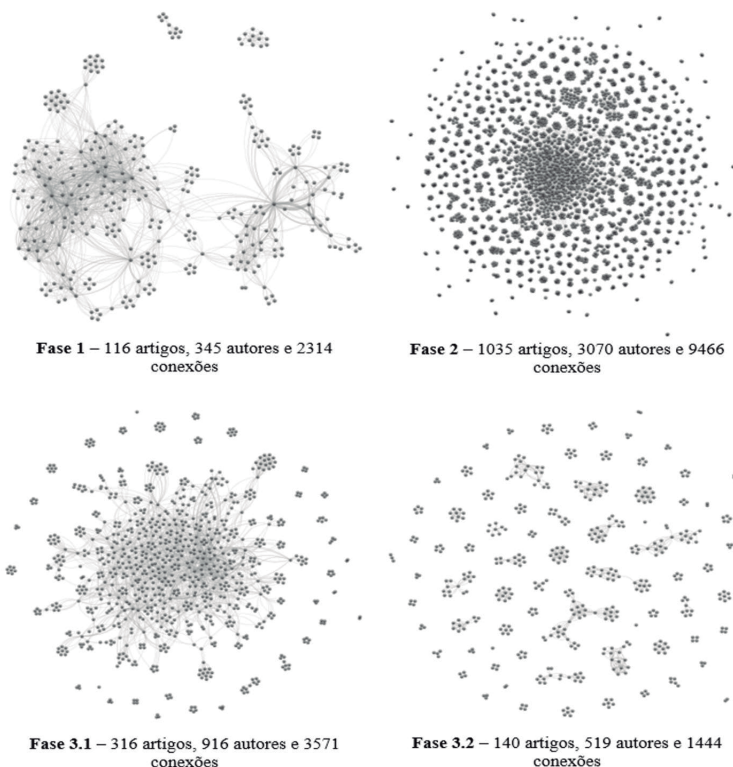
Figure 5 - Distribution of classes of words by occurrence and connections of works of origin in the United States.



Source: author’s construction.

The formation of networks resulted from the knowledge produced by the graduate Program in Nanosciences of the “*Centro Universitário Franciscano*” can be observed on the figure 6.

Figure 6 - Networks of articles, authors and connections resulting from Phase 1, Phase 2 and Phase 3 of the study.



Source: author’s construction.

The network resulting from phase 1, that is, the articles published by the graduate in Nanosciences Program have decentralized basic format, as described by Ferreira and Filho (2010). This fact allows to evaluate the existence in the network structure of groups with some distance from the main axis, having research groups with a centralized characteristic, possibly due to the framing of the subjects of study of the authors associated with the classes of knowledge presented in the figure 2. It was possible to observe the existence of 2,314 connections between the 345 authors involved in the construction of 116 articles published in the Scopus database.

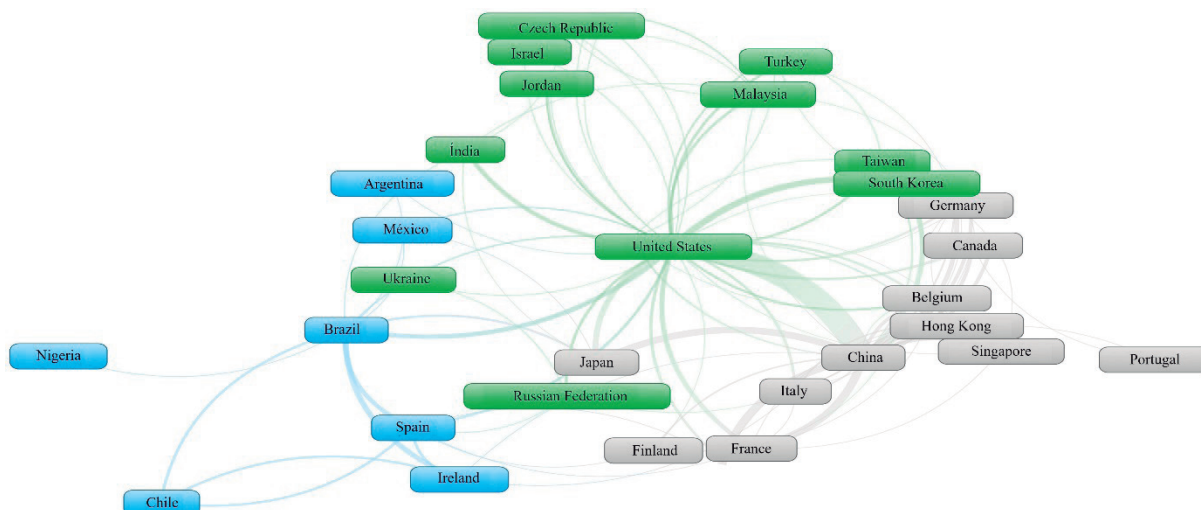
Looking for a relation presented by the articles, that cite the works published by the Nanoscience Program, one can observe a centralized structure. The data used in this construction are those of Phase 2, resulting from a greater symmetry in the 9,466 connections resulting from the involvement of 3,070 authors. In the formulation and publication of 1,035 articles that somehow used the knowledge developed by the Program.

Reducing the focus of the analysis of the networks, the articles base from Phase 3.1, that is, articles of origin in the China country, allow to observe a structure that presents characteristics of centralized, existing the formation of 3,571 connections among the 916 authors involved in the generation of 316 articles with citations to the knowledge of the Program.

The networks deriving from Phase 3.2, with the origin of the articles in the United States, allow us to observe a structure that presents dispersed characteristics with the generation of a volume of clusters, with the formation of 1,444 connections between the 519 authors involved in the generation of 140 articles with citations to the knowledge of the Program.

Thus, the networks constituted have potential for expansion of internationalization actions, for which figure 7 presents the relationship between the countries of origin of the authors that allowed the formulation of the networks of figure 6.

Figure 7 - Network of connection between authors and co-authors based on the country of origin and Phases of the study



Source: author's construction.

The figure 7 shows the international collaborative network resulting from this study and allows to observe the strong relationship between the studies conducted between researchers from the United States and China. The constitution of three clusters is based on the data base and the time account made for this study. In the blue clusters is presented the base of Brazilian researchers and the Program with its collaboration networks with emphasis on Spain.

The gray clusters is based on the researchers from China and presents the network of member countries of direct collaboration as well as for the relationship of studies with the green clusters that stems from the studies of the United States and the countries that collaborated on the articles evaluated by this study.

CONCLUSION

This article present a study about the development of the publications network that used the knowledge produced by the graduate Program in Nanoscience of the “*Centro Universitário Franciscano*” in relation to the axes of knowledge of the publications and constitution of the international relationship network as a form of validation and additional support to the internationalization process.

It was possible to evaluate the constitution of relationship class with study subjects of the main authors who used in their publications the knowledge generated by the Program, as well as verified the potential of interrelation with the countries that demanded more publications citing this knowledge. The highlight is China with 336 citations, with the focus being the class associated with the electronic structure and showing a better interrelation between the classes, perceived by the proximity of the same and by the collaborative network observed in these studies, having a greater capillarity of relationship between researchers.

In relation to the United States, which presented 156 citations, the context mainly surrounds nanotubes and silicon in its main associated class, and presents a slightly greater distance between its classes than China. The observation in relation to the general context of the citations of knowledge, it was possible to observe the prominence in the nanotubes, properties and electronic structure, in this general context is with more proximity to the proposition presented by the United States, but showing a greater distance between the classes of terms found in the distance of some classes. This fact reflected in the collaboration network of this country, presenting a distribution of the authors and a weak relation between the different groups.

In relation to collaboration networks, it was possible to evaluate that there are active links that connect the knowledge generated with the main groups of authors. The network is centrally structured to the main author in the overall evaluation. When the relationship between China and the United States is observed, it was possible to evaluate different patterns in the collaboration networks,

demonstrated by the greater connection and agglomeration to China and a greater distribution in the connections of the collaboration network of the United States.

The form of agglomeration of the collaboration networks presented in this study allows the internationalization process making effective the network of collaboration and the connection between the main groups of authors and knowledge.

It is worth highlighting for future work the construction of synergies among the authors involved in the different formats of networks presented, allowing the constitution of strategic actions to increase the impact of the developed knowledge and the sustainable expansion of the internationalization process.

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