A BIBLIOMETRIC ANALYSIS OF THE SCIENTIFIC PRODUCTION AND COLLABORATION BETWEEN GRADUATE PROGRAMS IN MANUFACTURING ENGINEERING IN BRAZIL

UMA ANÁLISE BIBLIOMÉTRICA DA PRODUÇÃO CIENTÍFICA E COLABORAÇÃO ENTRE PROGRAMAS DE PÓS-GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO NO BRASIL

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ABSTRACT

In Brazil, most of the scientific research is developed within the scope of the Brazilian university Graduate Programs, which host the Master's and Doctorate courses. These Graduate Programs are evaluated by the Coordination for the Improvement of Higher Education Personnel, an organ of the Brazilian Ministry of Education, which classifies the Graduate Programs in a ranking that ranges from 1 to 7, with 7 being the level of excellence. Among the inputs used by this evaluation process, there are the Brazilian researcher Lattes CVs, which contain all the details of the researchers' academic life, such as their academic background, areas of professional activity, intellectual production, student supervisions, collaboration networks, etc. The CVs of Brazilian researchers are publicly available for download in XML format. In this paper, we undertake a bibliometric analysis of the CVs taken from researchers who are part of a sample of Brazilian Graduate Programs in Manufacturing Engineering that have national ranking greater or equal to 4. For a period of 10 years (2008-2017), we sought to identify the most published topics, vehicles most used for publication, the basic training of the researchers, and the potential existence of collaboration networks between the Graduate Programs. Among other results, we could identify that 29 institutions are Alma Mater of 68.36% of the researchers analyzed. In addition, it was possible to verify that only two Brazilian scientific events account for 7.5% of the total of publications for the analyzed sample and period.

Keywords: Manufacturing Engineering. Bibliometric Analysis. Graduate Programs. Scientific Production. Scientific Collaboration.

RESUMO

No Brasil, a maior parte da pesquisa científica é desenvolvida no âmbito dos Programas de Pós-Graduação das universidades, que hospedam os cursos de Mestrado e Doutorado. Esses Programas de Pós-Graduação são avaliados pela CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), órgão do Ministério da Educação que classifica os Programas de Pós-Graduação em um ranking que varia de 1 a 7, sendo 7 o nível de excelência. Dentre os insumos utilizados nesse processo de avaliação, encontram-se os currículos Lattes dos pesquisadores brasileiros, que contêm todos os detalhes da vida acadêmica destes, tais como formação acadêmica, áreas de atuação profissional, produção intelectual, orientações, redes de colaboração, etc. Os currículos Lattes estão publicamente disponíveis para *download* no formato XML. Neste artigo, realizamos uma análise bibliométrica dos currículos Lattes de pesquisadores de uma amostra dos Programas de Pós-Graduação em Engenharia de Produção, classificados pela CAPES com nota maior ou igual a 4. A partir da análise de um período de 10 anos (2008-2017), buscou-se identificar os tópicos mais publicados, os veículos mais utilizados para publicação, a formação básica dos pesquisadores e a potencial existência de redes de colaboração entre os Programas de Pós-Graduação analisados. Entre outros resultados, pudemos identificar que 29 instituições de ensino superior respondem pela formação acadêmica de 68,36% dos pesquisadores da amostra. Além disso, foi possível verificar que apenas dois eventos científicos brasileiros representam 7,5% do total de publicações para a amostra e período analisados.

Palavras-chave: Engenharia de Produção. Análise Bibliométrica. Programas de Pós-Graduação. Produção Científica. Colaboração Científica.

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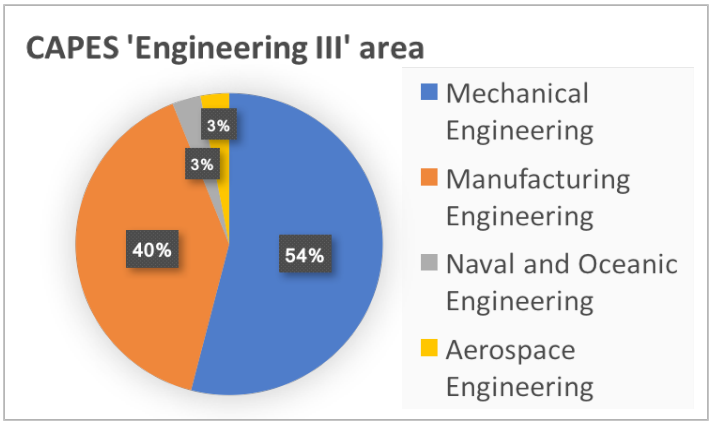
1 INTRODUCTION

The Coordination for the Improvement of Higher Education Personnel (CAPES)[5] is an agency of the Brazilian Ministry of Education whose central purpose is to manage and coordinate efforts to improve the quality of Brazil's faculty and staff in higher education. CAPES provides grant programs, through which it is particularly concerned with the training of Doctoral candidates, Pre-doctoral short-term researchers, and Post-Doctoral Scholars (IEE 2018). Among the various other responsibilities of this agency, there is the task of evaluating and classifying the Graduate Programs (GPs) in Brazil (IEE 2018; CAPES 2018). It is up to CAPES to establish specific rules for the systematics of this evaluation, detailing the steps, criteria and instruments used in this process (CAPES 2009). Among the indicators that are used by the CAPES's National Graduate System (NGS) to evaluate and classify GPs, we can highlight the following (CAPES 2012; CAPES 2016): GP Proposal; Researcher Training; Researcher Production; GP Student Body, Thesis and Dissertation; GP Research Lines; GP Research Projects; GP Intellectual Production; GP International Visibility; among others.

Under the procedural aspect, the GP evaluation system can be divided into two distinct processes that refer to the entry and permanence of the GPs in the NGS (CAPES 2009). Each GP is responsible for feeding annually – with its internal data – a platform made available by CAPES for this purpose (Sucupira). The information registered in the Sucupira platform is initially consolidated by a technical staff of CAPES. Next, they are sent to be analyzed by the so-called *area committees*, groups of ad-hoc experts who issue an opinion and a score for each GP, on a scale ranging from 1 to 7, with 7 being the score of excellence for Graduate Programs in Brazil. The results of the CAPES evaluation, which is done every 4 years, serve as the basis for generating the so-called *area documents*, which present the results of the four-year evaluation stratified by different areas of knowledge, and which serve as guidelines for institutional policies and for the strategic planning of the GPs of each area.

Fig 1 - Distribution of Graduate Programs in the CAPES area of Engineering III



Source: Own

5 http://capes.gov.br/

In September 2016, during the year the last evaluation was done, Brazilian NGS counted on 4256 Graduate Programs, distributed in 49 Evaluation Areas (Sucupira 2016). The Manufacturing Engineering GPs – the target of our analysis here – are part of the 'Engineering III' area, and represent 40% of all GPs in this area (Figure 1). Regarding the number of programs, Engineering III area is the eighth largest of CAPES and the largest among all engineering areas, with 128 programs (CAPES 2016). The Brazilian researchers register their academic activities on the Lattes Platform[6], which is an information system (integrated database, web-based query interface, etc.) maintained by the Brazilian Government to manage information on science, technology, and innovation related to individual researchers and institutions working in Brazil. Since all researchers and institutions are required to maintain their records up to date, Lattes Platform can be used not only to obtain information on individual researchers but also to conduct performance evaluations at the organizational level (Wikipedia 2016). All individual records are publicly available and can be downloaded in XML format.

In this work, we carried out a bibliometric analysis in a sample of the Graduate Programs in Manufacturing Engineering of Brazil best classified in the CAPES Engineering III area, through the collecting and processing of their researcher records, available on the Lattes Platform, during a time interval of 10 years (2008 - 2017). Objectively, in this work we sought to: i) Discover the most published topics by the analyzed groups, including the search for specific terms; ii) Establish the vehicles most published by the GPs in the analyzed time interval; iii) Quantitatively evaluate the GP publication, during the time period surveyed; iv) Identify the basic training of the researchers associated to the GPs (training courses, institutions, years of conclusion, and supervisors); v) Recognize existing collaboration networks, by means of student supervising, co-authoring of publications, co-participation in examining boards, and co-participation in research projects.

2 MATERIALS AND METHODS

a) Sample analyzed

From the last Brazilian GP classification done by CAPES in 2016, we chose to evaluate a sample of Manufacturing Engineering GPs that obtained a national score greater than or equal to 4. Table 1 shows the GPs selected for evaluation, which, combined, have a total of 213 researchers.

6 http://lattes.cnpq.br/

Table 1 – Graduate Programs analyzed

Institution Name	Acronym	CAPES Score	Number of researchers
UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL	UFRGS	7	33
UNIVERSIDADE FEDERAL DE PERNAMBUCO	UFPE	7	15
PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO DE JANEIRO	PUC-RJ	5	15
UNIVERSIDADE PAULISTA	UNIP	5	12
PONTIFÍCIA UNIVERSIDADE CATÓLICA DO PARANÁ	PUC-PR	5	13
UNIVERSIDADE FEDERAL DE SANTA CATARINA	UFSC	5	20
UNIVERSIDADE EST.PAULISTA JÚLIO DE MESQUITA FILHO/BAURU	UNESP	5	15
UNIVERSIDADE FEDERAL DA BAHIA	UFBA	5	22
UNIVERSIDADE DE SÃO PAULO	USP	4	22
UNIVERSIDADE FEDERAL DO RIO DE JANEIRO	UFRJ	4	17
UNIVERSIDADE FEDERAL DE SÃO CARLOS	UFSCAR	4	18
UNIVERSIDADE FEDERAL DE ITAJUBÁ	UNIFEI	4	11

Source: Own

b) Criteria for the CV data gathering

Table 2 – GP Websites

Institution	Website
UFRGS	http://www.ufrgs.br/producao/secao/P%C3%B3s_Gradua%C3%A7%C3%A3o-3
UFPE	https://www.ufpe.br/ppgepcaa/corpo-docente
PUC-RJ	http://www.puc-rio.br/ensinopesq/ccpg/progpro.html#docente
UNIP	https://www.unip.br/presencial/ensino/pos_graduacao/strictosensu/eng_producao/corpo_docente.aspx
PUC-PR	https://www.pucpr.br/escola-politecnica/mestrado-doutorado/engenharia-de-produc%CC%A7a%CC%83o-e-sistemas/
UFSC	http://ppgep.ufsc.br/
UNESP	http://www.feb.unesp.br/#!/pos-graduacao/ppgep/corpo-docente/
UFBA	http://www.pei.ufba.br/corpo-docente
USP	http://ppgep.poli.usp.br/corpo-docente/
UFRJ	http://www.coppe.ufrj.br/pt-br/programas/engenharia-de-producao
UFSCAR	http://www.ppgep.dep.ufscar.br/?page_id=209
UNIFEI	https://sigaa.unifei.edu.br/sigaa/public/programa/equipe.jsf?lc=pt_BR&id=334

Source: Own

We analyzed the CVs of all 213 researchers associated to the selected GPs. For this identification, we visited the websites of the 12 selected GPs (Table 2), in order to collect the researchers' Lattes Platform ID and/or their full name, since both are search terms on the Lattes Platform. Once all researchers were identified, their respective CVs in XML format were downloaded from the Lattes Platform between July 02 and 03, 2018. Finally, it was defined that the data to be analyzed should belong to a closed time interval of 10 years: 2008 to 2017.

c) Discovery of the most published topics and identification of research opportunities

By means of searching in titles and keywords of the works published by GP researchers, it was possible to identify the most published topics, besides any possible research opportunities. In order to analyze the most relevant terms used by the researchers, we applied the Zipf's Law (1949), which deals with the distribution and frequency of words in the texts and produces a small universe of the more representative terms. This set of representative terms could lead to new more objective searches by third parties or, still, potentially identify research trends/opportunities in the Manufacturing Engineering area in Brazil, from a point of view of the analyzed sample.

d) Establishment of vehicles (scientific events and journals) most published by the GPs

We applied the Bradford's Law (1934), known as a method of dispersion of scientific literature, to identify the conferences (and scientific events, in general) and journals most used by GP researchers to publish their work in the analyzed period.

e) Quantitative evaluation of the GP publication during the time interval surveyed

In order to concentrate all the publication records gathered in the analyzed sample, we labeled these productions as: Web of Science 1 (WoS 1), for journals with high impact factor and high average lifetime (according to the *area document* of CAPES Engineering III area) (CAPES 2016; CAPES 2017); Web of Science 2 (WoS 2), for journals with high impact factor and intermediate average lifetime (CAPES 2016; CAPES 2017); Web of Science 3 (WoS 3), for journals with low impact factor and intermediate average lifetime (CAPES 2016; CAPES 2017); Book; Book Chapter; Scientific Event Paper; and journals that are indexed in other databases.

f) Identification of the basic GP researcher training

For each GP researcher, the following information on training records was extracted from his/her Lattes CV:

- Training Type;
- Training Name;
- Training Institution;
- Year of Conclusion;
- Training Supervision.

We collected data for the following types of training: (i) Undergraduate Degree; (ii) Complementary Undergraduate Degree; (iii) Master's Degree; (iv) Complementary Master's Degree; (v) Doctoral Degree; (vi) Complementary Doctoral Degree; and (vii) Other Type of Complementary Training. In addition, we collected data on the Post-Doctoral Research periods, a type of activity that only provides research institution name and year of completion.

g) Recognition of the existing collaboration networks among GPs

Through the extraction of data from the Lattes CVs of the 213 researchers and the subsequent cross-linking between them, it was possible to identify networks of collaborations between the analyzed GPs.

Each researcher needs to record his/her student supervisions, publication co-authoring, examination board co-participation, and research project co-participation. By means of cross-referencing each co-partnership name with the names of the 213 researchers analyzed, it was possible to recognize the existence of links between them in each of these categories.

h) Supporting tools

ProspectorWare – a software developed to process Lattes-like XML files –, Microsoft Excel and IBM SPSS were used by us as base tools for this work. The tag cloud shown in Figure 2 was built by using the Kumo Word Cloud API[7] plugin.

7 https://github.com/kennycason/kumo

3 RESULTS

3.1 Discovery of the most published topics by GPs, including the search for specific topics

For our analysis, we used the term with the highest frequency “Analise n = 413” and raised it to the square root, resulting in 64.28 terms, in which we rounded up to 64 terms out of a total of 17,174 terminologies. The studied universe represented 0.37% (64) of the terms (n = 83,604), and its frequency concentration was 22.34% of a total frequency (n = 374,157). Figure 2 shows us a tag cloud that illustrates this scenario.

Fig 2 - Tag cloud with the most frequently research topics

Source: Own

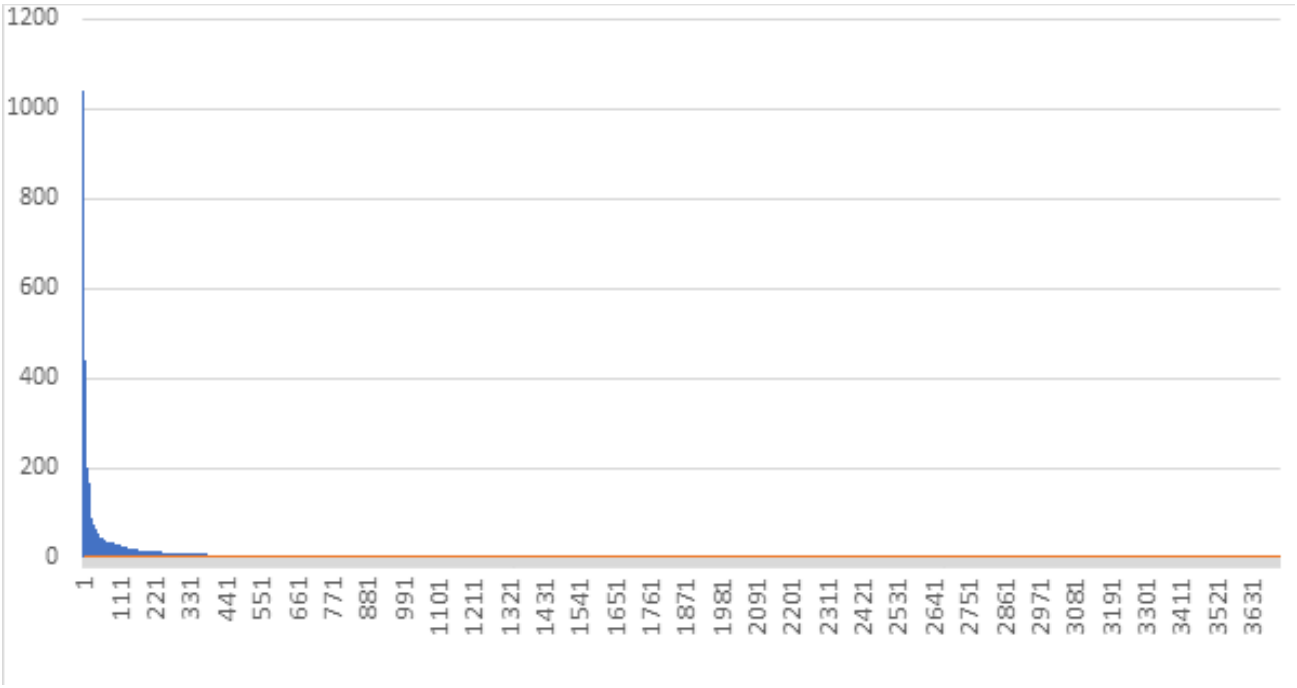
The most representative terms are: 'análise' n = 4133, 'gestão' n = 3847, 'estudo' n = 3172, 'desenvolvimento' n = 2591, 'avaliação' n = 2149, 'caso' n = 2108, 'management' n = 2062, 'produção' n = 2033, 'analysis' n = 1856, and 'processo' n = 1777.

Within the terminologies represented, we have some isolated terms that stood out more than others, as it is shown in the tag cloud, but it was possible to find some compound terms that are considered as trends of original studies in Brazilian Manufacturing Engineering. These terms are (in Portuguese): 'ciclo de vidas das organizações' (lifecycle of organizations) and 'estágios do ciclo de vida' (stages of lifecycle), which are studied by researchers from the Federal University of Santa Catarina (UFSC) and the Federal University of São Carlos (UFSCar). We can conclude there is a potential trend of these original studies being disseminated in scientific events of engineering.

3.2 Scientific events and journals most used by GPs for publication

In the case of the dispersion of publications by Bradford, we have in the first sphere 47 vehicles that represented 33.06%; in the second sphere, 333 vehicles that represented 31.21%; and, in the last sphere, 3342 vehicles that totaled 35.73%.

Fig 3 – Dispersion of publications (Bradford's Law)



Source: Own

In the typology of the first sphere, we have a greater emphasis on Brazilian scientific events, like the National Meeting of Manufacturing Engineering n = 1126, the Manufacturing Engineering Symposium n = 792, the Brazilian Symposium on Operational Research n = 412, and the Brazilian Congress of Manufacturing Engineering n = 107. Regarding international scientific events, we obtained the following: the International Conference on Industrial Engineering and Operations Management n = 203, followed by the International Workshop on Advances in Cleaner Production n = 180, the International Conference on Manufacturing Research n = 178, and the Advances in Manufacturing Management Systems n = 97. Concerning the journals with high impact factor (WoS 1), those that stood out were the Journal of Cleaner Production n = 185, followed by the International Journal of Production Economics n = 102, and the European Journal of Operation Research n = 51.

Regarding the journals with intermediate impact factor (WoS 2), there is the International Journal of Production Research n = 57. When considering the journals with impact factor not exceeding 1.5 (WoS 3), we have the International Journal of Advanced Manufacturing Technology n = 81. Next, there are the WoS 4 journals, those that are indexed in the Web of Science but do not have impact factor: WORK-A Journal of Prevention and Rehabilitation n = 71; and IEEE Latin America Magazine n = 69. Finally, there are the journals that are not indexed in the Web of Science: Produção n = 349, Gestão & Produção (UFSCar) n = 255, Espacios n = 240, Revista Produção Online n = 219, GEPROS n = 91, Product n = 80, Revista Gestão Industrial n = 80, Revista SODEBRAS n = 64, Produto & Produção n = 61, Brazilian Journal of Operations and Production Management n = 60, and Gestão & Produção n = 49.

3.3 GP publication in the analyzed time period

When considering the scientific works published in WoS 1 category, we have ¼ of the institutions (UFBA n = 101, UNIP n = 83, and UFRGS n = 80) representing 36.46% of the source of high impact works. Concerning the works published in WoS 2 journals, we identified 40.24% of the institutions (UFBA n = 119, UFRGS n = 70, and PUC-PR n = 69) as the source of them. Finally, WoS 3 journals presented a proportion of 35.04% of the source institutions (PUC-RJ n = 106, PUC-PR n = 87, and UNIP n = 73). It is worth mentioning that Web of Science-indexed publications are the ones that score the most for Brazilian NGS and possess a weight from around 50% to 60% out of all the qualified production, in general.

Table 3 – Number of publications by category

Institution	WoS 1	WoS 2	WoS 3	Book	Book Chapter	Scientific Event	Other Categories
UFBA	101	119	70	7	78	1287	151
UNIP	83	63	66	35	118	897	198
UFRGS	80	70	87	59	200	1543	109
PUC-PR	79	69	73	9	117	1241	83
UNESP	66	53	48	22	45	924	72
UFRJ	60	52	69	47	132	468	115
USP	57	20	52	48	147	915	59
PUC-RJ	52	34	47	11	32	645	45
UFPE	44	19	32	6	21	610	12
UNIFEI	40	51	106	29	31	613	48
UFSC	31	36	47	44	220	1934	247
UFSCAR	31	55	62	44	106	966	57

Source: Own

The other 40% of the qualified production of the sample are divided between journals without impact factor, journals indexed in Scopus[8] or SciELO[9], scientific-event papers, and book and chapter book publications. As for publication vehicles that have no impact factor or are indexed in Scopus and SciELO, it is only possible to control their visibility and representation within the classification system because they provide online access and, consequently, also carry out some impact on the network.

However, the evaluation of book and book chapter publications is quite subjective, since it can be identified some criteria related to the "importance" of the vehicle for the scientific community, but without actually being possible to identify a quantitative standard to follow. Concerning scientific-event papers, CAPES' areas of knowledge use to search for the most representative ones in open systems, such as Google Scholar. The analysis of scientific-event production also had ¼ of universities representing 39.55% of the total (with emphasis on USP n = 1934, UNIP n = 1543, and PUC-RJ n = 1287).

3.4 Basic training of GP researchers

Researcher training is an indicator that stands for 30% of CAPES NGS score for GPs. CAPES NGS system takes into account the quality of institution regarding the Undergraduate, Master's and

8 https://www.scopus.com/home.uri
9 http://www.scielo.org/php/index.php

Doctorate Degrees taken by researchers. More recently, it also qualifies as very important a period of Post-Doctorate research undertaken elsewhere.

Table 4 – Researcher base training

Institution	Undergraduate Degree	Master's Degree	Doctorate Degree	Co-Supervision	Post-Doctorate	Others
USP	34	36	50		7	12
UFRGS	29	27	25		20	4
UFSC	8	25	18			
UFRJ	13	21	8			2
PUC-RJ	13	11	10		2	2
UFPE	9	12	15		2	
UNICAMP	4	15	12		1	2
UFBA	15	7	4		1	5
UFSCaR	7	8	7		2	1
UNESP	10		1			9
UNIFEI	6	6	2		1	1
UFSM	9	3	1			1
POLI-USP	3	3	3			3
FGV		2	3			4
PUC-PR	4	2	2		1	
POLI MILANO			2	2	4	
CONS NAT ARTS METIERS		2	2		1	2
UNIP		4	1		1	1
UFF	4	1	1			
UNIV MET PIRACICABA	2	1			1	2
UERJ	5					
UNIV TEXAS AUSTIN				2	3	
UNIV WATERLOO			1	1	3	
NORTH CAROLINA ST UNIV					4	
UNIV POLI MADRID			1	1	2	
UNIFRAN	2					2
UFJF	3					1
UNIV LONDON					4	
UNIV SOUTHAMPTON			1	2	1	

Source: Own

The institutions shown in Table 4 represent only 12.29% of all training institutions identified in the sample. However, interestingly, they are associated with 68.36% of all GP researcher training documented. At the Undergraduate Degree level, 19 universities (7.78%) are responsible for 73.77% of the training. At the Master's Degree level, we have 18 universities (7.37%) responsible for 89.42% of the training. Regarding the Doctorate Degree, there are 22 institutions (9.01%) responsible for 79.06% of the training. Concerning the Post-Doctorate research periods, it was possible to identify that 19 institutions (7.78%) accounted for 36.30% of the total.

Next, still by means of the training analysis, Table 5 presents the researchers who most supervised the training of other researchers belonging to the sample. It is important to remark, however, that not all the supervisors below belong to the sample.

Table 5 – Student Supervision

Supervisor	Undergraduate Degree	Master's Degree	Doctorate Degree	Co-Supervision
José Luis Duarte Ribeiro	8	11		
Adiel Teixeira de Almeida Filho	2	4	7	1
Marcos Nereu Arenales	6	4		
Afonso Carlos Correa Fleury	1	3	5	
Ana Paula Cabral Seixas da Costa	1	2	5	
Flávio Sanson Fogliatto	5	2		
Francisco José Kliemann Neto	4	3		
Daisy Aparecida do Nascimento Bebelatto	1	2	2	
Marcelo Embiruçu de Souza	1	1	2	1
Alexandre Street de Aguiar	1	1	1	1
Luis Antonio Lindau	1	3		
Mario de Jesus Mendes	1	3		
Nelson Back	2	2		
Nivaldo Lemos Coppini	3	1		
Pedro Luiz de Oliveira Costa Neto	1	3		
Silvio Hamacher	2	2		

Source: Own

Consequently, 4.03% of the researchers (16) supervised 13.79% of the GP researchers, including the ones who has not informed his/her supervisor. When considering only the GP researchers who informed his/her supervisor, these same 16 researchers supervised 19.34% of the total.

Regarding training courses, Table 6 shows the most studied ones by GP researchers.

Table 6 – Training Courses[10]

Course	Under-graduate Degree	Master's Degree	Doctorate Degree	Co-Supervision	Post-Doctorate	Others
Manufacturing Engineering	24	97	96	102		2
Post-Doctorate					167	
Civil Engineering	61	1	2	2		
Chemical Engineering	22	12	10	8		
Mechanical Engineering	20	15	14			
Electrical Engineering	15	13	11	9		
Full-Professor Training[10]						25
Business	7	1	4	4		
Business and Enterprise Management	7	2	3	3		
Computer Science and Computer Mathematics		6	2	2		
Transportation Engineering		5	3	1		
Mathematics	6	2	1			
Physics	3	3	2			
Economic Sciences	6	1				
Mechanical Production Engineering	7					
Ergonomics		3	3			1
Statistics	3	3	1			
Mathematics Teaching	7					
Computer Science	2	2	2			
Economy	4					1
Industrial Engineering	1	1	3			
Architecture and Urbanism	2	1	1			
Food Engineering	1	1	1	1		
Physics and Chemistry		2	2			

Source: Own

When we consider the whole training course universe analyzed, 11.53% (24) of training courses were responsible for 39.50% of the training at all levels. But if we divide

10 Training required by some universities in the state of São Paulo.

them into categories, the results also remain very representative. The training courses shown in Table 6 stand for 36.26% of the total in Undergraduate Degree category (out of 209 courses identified in the sample); 40,71% in Master's Degree category; and 37.26% in Doctorate Degree category.

One curiosity identified during the analysis concerns the periods in which the GP researchers undertook their postdoctoral stages. A large number of researchers did their postdoctoral research in 2016 (n = 14), followed by the year 2015 (n = 13) and 2008 (n = 12), as the most representative ones. As for Doctorate Degree training, we have the year 2012 as the most representative (n = 13); followed by the years 2010 and 2009 (both with n = 12). In this category, there are also some researchers who undertook their Pre-doctoral short-term research periods (known in Brazil as "Doctorate Sandwich Internship") in the years 2012 (n = 13) and 2011 (n = 11). Regarding the training courses took in Master's Degree category, we have as a representative year 1996 (n = 12); followed by the years 2005 and 2008, (both with n = 10). Finally, in Undergraduate Degree category, the representative years are 1983, 1988 and 1996 (all of them with n = 10).

It is possible to relate the periods of greater evolution of GP researchers' training with a Brazilian national training policy for Doctoral and Post-Doctoral levels, especially from some initiatives taken by the governments Lula da Silva (2003-2010) and Dilma Roussef (2011-2016).

3.5 Collaboration networks through student supervision, co-authoring of works, co-participation in examining boards, and co-participation in research projects

The student supervisions (Table 7), especially those at the Master's and Doctorate Degree levels, presented a very great degree of *endogeny* (here considered as the situation where researchers took training courses in the same institution in which they work). As an example, this scenario was identified for UFRGS (with n = 16 for Doctorate Degree and n = 13 for Master's Degree); UFPE (Doctorate Degree n = 7) and PUC-PR (Doctorate Degree n = 5).

A curiosity detected was the number of researchers from UFSC (Doctors n = 5 and Masters n = 5), state of Santa Catarina, who took their Master's and Doctorate Degrees in UFGRS, state of Rio Grande do Sul, showing that the geographical criteria facilitates the partnership, since both states are located in the Southern Region of Brazil.

Table 7 – Collaboration in student supervisions

Supervisor Institution	Student Institution	Undergraduate Degree	Master's Degree	Doctorate Degree	Others	Total
UFRGS	UFRGS		13	16		29
UFPE	UFPE	2	3	7		12
UFRGS	UFSC		5	5		10
PUC-PR	PUC-PR			5		5
PUC-RJ	PUC-RJ		4		1	5
USP	USP		2	3		5
UNIFEI	UNIFEI	1	2	2		5
UFBA	UFBA		3	1		4
UFRJ	UFRJ		1	3		4
UFPE	Not informed		2	1		3
UFSC	UFSC		1	2		3
UFRGS	Not informed		3			3
UFRGS	Not informed			3		3
Teleint. RNatEdu	UNIP		1	1		2
USP	Not informed		1	1		2
Not informed	UFRGS	1				1
PUC-RJ	UFRGS		1			1
Teleint. RNatEdu	UNIFEI			1		1
USP	POLI USP	1				1
USP	UNESP			1		1
USP	UFSCar			1		1
USP	UNIP			1		1
UFBA	UFSB			1		1
UFSC	UFPE		1			1
UFSC	UNIFEI		1			1
UFSC	PUC-PR			1		1
UFSCar	UFSCar		1			1
UFSCar	UNESP			1		1
UFRGS	UFSCar		1			1
UFSB	UFBA				1	1
UNIP	POLI USP	1				1
UNIP	UFSCar		1			1
UNIP	USP		1			1

Source: Own

We identified 9 scenarios concerning the representation of work co-authorship, by typology. Table 8 shows us them, along with their Bradford's Law visibility.

Table 8 – Co-authoring institutions by type of publication

Total	Co-author Institution	Co-author Institution	Publication Vehicle	% Bradford
35	UFRGS	UFRGS	Book	
21	UNIP	UNIP	Book	
12	Montpellier Bus School	UFSC	Book	38,85%
179	PUC-PR	PUC-PR	Book Chapter	
45	UFRGS	UFRGS	Book Chapter	
43	UFSC	UFSC	Book Chapter	46,27%
649	PUC-PR	PUC-PR	International Scient. Event	
263	UNIP	UNIP	International Scient. Event	38,51%
283	UFBA	UFBA	National Scient. Event	
238	UFSC	UFSC	National Scient. Event	
200	UFRGS	UFRGS	National Scient. Event	41,36%
346	UFSC	UFSC	Other Categories	
268	UFRGS	UFRGS	Other Categories	
200	PUC-PR	PUC-PR	Other Categories	37,84%
147	UNIP	UNIP	WoS 1	
68	UFBA	UFBA	WoS 1	43,17%
99	UFBA	UFBA	WoS 2	
83	UNIP	UNIP	WoS 2	42,52%
157	UNIFEI	UNIFEI	WoS 3	36,94
34	UFSC	UFSC	WoS 4	
32	UNIFEI	UNIFEI	WoS 4	35,29%

Source: Own

The main partnership detected was through Book Chapter publications, in which 3 institutional co-authors represented 46.27%. Unfortunately, all these partnerships involved researchers from the same institution. Regarding the co-authorship in Book publications, there was also 3 partnerships representing 38.85% of the total, however, in this case, one of the co-authorship involve different institutions: UFSC and Montpellier Business School. In papers presented at Brazilian scientific events,

we also had 3 partnerships (all of them within the scope of the same institutions) that were responsible for 41.36% of the publications. When considering publications in international scientific events, the proportion dropped to 2 partnerships (again, within the scope of the same institutions) representing 38.51% of the total. Concerning publications in Web of Science journals, we have 43.17% for WoS 1 category; 42.52% for WoS 2 category; 36.94% for WoS 3 category; and 35.29% for WoS 4 category.

Table 9 shows us the analysis of co-relations in the form of co-participations in examination boards (Undergraduate Degree, Master's Degree, and Doctorate Degree). Nevertheless, the indexation of the researchers' data in their Lattes CVs hampered most of the partnership identifications, as it can be seen below.

Table 9 – Co-participation in examination boards

Total	Co-Participant 1	Co-Participant 2	Training Level	% Bradford
95	Not informed	UFSC	Undergraduate Degree	
85	Not informed	UFRGS	Undergraduate Degree	33,39%
261	Not informed	UFRGS	Master's Degree	
188	Not informed	USP	Master's Degree	
178	Not informed	UFSCar	Master's Degree	39,86%
336	Not informed	USP	Doctorate Degree	
201	Not informed	UNIP	Doctorate Degree	35,56%
48	UFSC	USP	Other Trainings	57,14%

Source: Own

It is, however, important to notice that two institutions were present in 33.39% of the Undergraduate Degree examination boards; three other institutions accounted for 39.86% of the Master's Degree examination boards; two others were in 35.56% of the Doctorate Degree examination boards; and, the only identified co-participation in examination board is in the Other Trainings level (such as Specialization or Improvement trainings) with a partnership between UFSC and USP in 57.14% of the examination boards.

Finally, the co-participation in research projects – involving at least one GP of the analyzed sample – were identified. Table 10 shows us that 39.37% of the partnerships occurred: (i) between UFRGS researchers and themselves; and (ii): between UFBA and UFSB (the Federal University of South Bahia, which does not belong to the analyzed sample). That scenario shows us again that geographical proximity is a facilitator of scientific partnerships in Brazil, since the territorial extension of this country is quite significant and regionalizing partnerships facilitates personal and physical interaction.

Table 10 – Co-participation in research projects

Total	Co-Participant	Co-Participant	% Cumulative
322	UFRGS	UFRGS	22,16
250	UFBA	UFSB	17,21
168	PUC-PR	PUC-PR	11,56
128	UNIFEI	UNIFEI	8,81
86	POLI USP	USP	5,92
79	UFSCar	UFSCar	5,44
65	UFSC	UFRGS	4,47
54	UFPE	UFPE	3,72
48	UFSC	UFSC	3,30
33	Not informed	UFRGS	2,27
26	USP	UFSC	1,79
24	UFSC	Univ South Carolina	1,65
19	UNESP	UNESP	1,31
18	UFRJ	UFRJ	1,24
13	UNESP	UFSCar	0,89
12	UFRGS	Univ South Carolina	0,83
108	33 Universities	33 Universities	7,43

Source: Own

Concerning all the analyzed sample, the GPs that most established partnership in research projects were UFRGS (n = 420), followed by UFBA (n = 250), UFSC (n = 163), USP (n = 112), and UFSCar (n = 92).

4 CLOSING REMARKS

In this work, we analyzed a sample of Brazilian Graduate Programs in Manufacturing Engineering (CAPES Engineering III area). We were able to discover the research topics most used by the GPs, as well as to present some examples of recent topics that may become a future research opportunity within the Engineering III area. The other criteria analyzed in this paper (scientific publication, researcher training, and collaborative networks) are an integral part of CAPES' NGS evaluation system for GPs in Brazil. CAPES NGS, despite having its flaws, is quite efficient. The partnership between its area committees facilitates the adaptation of general rules to specific areas of knowledge, which have their own dynamics and idiosyncrasies.

Scientific publications in journals play a central role in CAPES evaluation system, especially those that possess high impact factor, as it is the case of Web of Science-hosted journals. These journals even influenced the creation of internal Brazilian categories for journal evaluation, which comprises subgroups of journals gathered according to their Web of Science impact factor. Regarding scientific events, CAPES uses to consider the publication of more *dynamic* papers, many of them even still in intermediate stages of development in relation to their final outcomes. It is important to notice, however, that each CAPES area is free to classify scientific events and journals according to their specificities.

Furthermore, it may be argued that some evaluation criteria, especially those related to some types of publications, such as books and book chapters, may in some cases be overly subjective. Nevertheless, this type of publication has a weight in the final classification of the GPs. In addition to publication quantification, GPs are evaluated by the average training of their researchers. Our study identified that, on the contrary to what CAPES asks, some GPs possess some degrees of *endogeny* in the training of some researchers, a criterion that is disregarded by CAPES in its NGS. However, in general, we believe that CAPES NGS has worked very well in recent years.

As for future work, we intend to reapply this analysis to other samples. Eventually, undertake a complete analysis of all GPs of a particular area of knowledge, in order to extract a most accurate screenshot of the moment. In addition, it is possible to apply Social Network Analysis techniques to study in more detail the partnerships and collaboration networks identified in this study.

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