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# Characteristics of scientific collaboration among research groups in areas of exact sciences, biology and humanities

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## Abstract

This study aims to characterize the scientific collaboration (SC) among research groups, active in the different areas of knowledge (exact sciences, biology, and humanities). It addresses the reasons for collaboration; interaction dynamics; facilitator aspects, challenges, problems and difficulties faced; main results achieved; and learned content. It is a theoretical, empirical, descriptive and qualitative research, based on a literature review that describes the panorama of studies on this subject. Data collected by semi-structured interview were organized in categories of analysis defined “a priori” and submitted to content analysis. The results identified that collaboration is driven by the need to meet the requirements of funding agencies and are aimed especially at: 1) the expansion of studies and research, with diversification of theoretical and methodological perspectives, with the objective of obtaining greater knowledge about the subject, in addition to the use and exchange of knowledge and experience of other members of the SC; and 2) sharing of financial resources and equipment. The proximity of the research groups line of study and the prior relationship among the researchers, which is gained in opportunities of study and interaction (events), contribute to form partnerships for scientific collaboration. There is an overlap between challenges, problems, hindering and facilitating aspects, with the presence or absence of certain conditions determining how the aspect is perceived. Among the main results are the best use of resources, quality improvement, production expansion, and the knowledge dissemination. In addition to focusing on the theme in the context of Brazilian research groups of different areas of knowledge, the study contributes to the identification of contents learned in the performance in SC..

**Keywords:** Scientific collaboration. Research groups. Results of scientific collaboration.

## *Características da colaboração científica entre grupos de pesquisa de áreas de exatas, vida e humanas*

### Resumo

Este estudo caracteriza a colaboração científica (CC) entre grupos de pesquisa (GP), atuantes nas áreas de exatas, vidas e humanas, abordando motivos da colaboração; dinâmica de interação; facilitadores, desafios, problemas e dificuldades enfrentados; principais resultados alcançados; e conteúdo aprendido. A pesquisa, de natureza teórico-empírica, descritiva e qualitativa, pautou-se em revisão bibliográfica para situar o panorama de estudos acerca dessa temática. Os dados coletados com base em roteiro de entrevista semiestruturado foram organizados em categorias definidas *a priori* e submetidos a análise de conteúdo. Os resultados indicam a necessidade de parcerias para atender a editais de fomento ou visando principalmente: 1) à ampliação de estudos e pesquisas, com diversificação de perspectivas teóricas e metodológicas, com o objetivo de obter maior conhecimento a respeito do tema, além do aproveitamento e troca de conhecimentos e experiência de outros integrantes da CC; e 2) ao compartilhamento de recursos financeiros e equipamentos. Contribuem para a formação de parcerias a proximidade entre as linhas de pesquisa e o conhecimento prévio dos pesquisadores, decorrente de situações de formação ou interação em eventos. Há sobreposição entre desafios, problemas, aspectos dificultadores e facilitadores, sendo a presença ou ausência de algumas condições determinante de como aquele aspecto é percebido. Entre os principais resultados estão o melhor aproveitamento de recursos, a melhoria da qualidade e a ampliação da produção e da disseminação do conhecimento. Além de focar o tema em contexto de GP brasileiros de diferentes áreas do conhecimento, o estudo contribui com a identificação de conteúdos aprendidos na atuação em CC.

**Palavras-chave:** Colaboração científica. Grupos de pesquisa. Resultados de colaboração científica.

## *Características de la colaboración científica entre grupos de investigación de áreas de exactas, vida y humanas*

### Resumen

El objetivo de este estudio es caracterizar la colaboración científica (CC) entre grupos de investigación (GI) que operan en diferentes áreas del conocimiento (exactas, vidas y humanas), abordando los motivos de la colaboración; dinámica de la interacción; facilitadores, retos, problemas y dificultades enfrentados; los principales logros y el contenido aprendido. La investigación, de naturaleza teórico-empírica, descriptiva y cualitativa, se basó en la revisión de la literatura para situar el panorama de estudios sobre este tema. Los datos recolectados basados en un guión de entrevistas semiestructurado se organizaron en categorías definidas *a priori* y se sometieron a análisis de contenido. Los resultados identifican la necesidad de alianzas para satisfacer las convocatorias de fomento o principalmente para: 1) la ampliación de estudios e investigaciones, con diversas perspectivas teóricas y metodológicas, con el objetivo de obtener mayor conocimiento sobre el tema, además del aprovechamiento e intercambio de conocimientos y experiencias de otros miembros de la CC; y 2) la compartición de recursos financieros y equipos. Contribuyen a la formación de alianzas la proximidad entre las líneas de investigación y el conocimiento previo de los investigadores, resultantes de situaciones de formación o interacción en eventos. Hay superposición entre desafíos, problemas, aspectos dificultadores y facilitadores, y la presencia o ausencia de ciertas condiciones determinan cómo se percibe este aspecto. Entre los principales resultados están el mejor uso de los recursos, la mejora de la calidad y el aumento de la producción y difusión de conocimientos. Además de centrar el tema en el contexto de GI brasileños de diferentes áreas del conocimiento, el estudio contribuye a la identificación de los contenidos aprendidos en la actuación en la CC.

**Palabras clave:** Colaboración científica. Grupos de investigación. Resultados de la colaboración científica.

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## INTRODUCTION

Nowadays, the demand for a greater development of human potentials and knowledge is noticeable to expand knowledge production and to continuously develop determinate competences (ODELIUS, ABBAD, RESENDE JUNIOR et al., 2011) and the Universities assume an important role in science advancement as a source of knowledge construction. In this context, postgraduation programs are distinguished for forming researchers, masters and doctors who will contribute to produce new types of knowledge (LEITE FILHO and MARTINS, 2006), and research groups (RG) that aim to generate and to disseminate knowledge beside exchanging information on different subjects.

The formation of a RG is recognized as an important factor for the advancement of scientific knowledge in academic and professional fields, because it is a propitious context for scientific research and knowledge production (GATTI, 2005); for the development of complex competences and the achievement of other results, like creation of networks, contribution to recognition and visibility (national and international) of knowledge created by the group and formation of masters and doctors (ODELIUS, ABBAD, RESENDE JUNIOR et al., 2011).

In addition to studies related to RG, there is a significant increase in studies about scientific collaboration (SC) that address among several aspects: contributions in the academic field (ANTONIALI, SILVA PENIDO, BAZANI et al., 2013); importance of combining knowledge from different areas for joint development of theories and investigations, that result in an extended study and expansion of its scope (HAYASHI, HAYASHI, MARCELO et al., 2012).

The identification of differences between areas, regarding adoption and acting in collaboration, and the emphasis given to the quality of the collaboration itself with pressure of increased production contributes to the development of studies addressing: quantitative growth of production (LEITE, CAREGNATO, LIMA et al., 2014); reasons for establishing collaboration (CHITUC and AZEVEDO, 2005); demands, results and consequences of the performance in SC and structures of relationships between researchers, RG and research institutes (ACEDO, BARROSO, ROCHA et al., 2006; WATANABE, GOMES and HOFFMANN, 2013); contribution of information and communication technologies and information sharing among groups (BALANCIERI, BOVO, KERN et al., 2005); competences necessities to the formation of doctors in Brazil (RAMOS and VELHO, 2013); internationalization processes (of research and postgraduation) and SC (MENANDRO, LINHARES, BASTOS et al., 2015). In addition to these, Soares, Souza and Moura (2010, p. 528) highlighted:

[...] identification of processes of collaboration development (FAFCHAMPS and VAN DER LEITE GOYAL, 2006); consolidation of interdisciplinary research [...]; extension of the disciplinary expertise [...]; structure of postgraduation programs [...]; patterns and style of collaboration [...]; motivations, strategies and effects of collaborative research [...]; evolution of co-authored texts [...]; institutionalized patterns of production [...]; connections between co-authors in some specific departments [...]; relation between co-authorship and production [...]; and other themes.

Reviewing the literature of SC, Vanz and Stumpf (2010) present concepts and history of the first occurrences of collaborative works, demonstrating that SC is not a new phenomenon. However, Figg, Dunn, Liewehr et al. (2006) emphasize that, despite the growing emphasis on collaboration in scientific research, little is known about the extent of collaborations and Martins and Ferreira (2013) point out the necessity of knowing the causes and reasons that influence the way that researchers articulate and construct their SC networks. But Leite, Caregnato, Lima et al. (2014), with the purpose of establishing qualitative and quantitative evaluation indicators that address collaboration processes in addition to products resulting from the SC, point out that they had difficulties in finding articles about the subject.

Considering these demands, the questions that marked this study were:

1. Which are the objectives and reasons that lead researchers to work in SC?
2. How SCs start and develop?
3. Which aspects facilitate and constrain these interactions?
4. Which were the results achieved?

Therefore, this study aims to characterize collaboration in Brazilian RGs, describing reasons for collaboration; interaction dynamics; challenges, problems and difficulties faced; facilitators to perform in SC; main results achieved; and content learned in groups of exact, biological and human sciences. To achieve these objectives, studies about RG and SC are initially addressed,

followed by methodology applied, results and discussion of discoveries. Finally, the conclusion, limitations and suggestions for future researches are presented.

## Research group

Correa (2007) defines RG as a set of individuals working in teams that focus on achieving a common goal, usually the solution for a research problem with an identified gap that creates, at the same time, scientific advance and development of new knowledge by the members of the group. In addition, Odelius, Abbad, Resende Junior et al. (2011, p. 202) point out that “a research group corresponds to [...] researchers, teachers, students and technical support staff that can organize themselves around research lines” and share resources, knowledge, physical facilities with the purpose of generate scientific knowledge.

This collaborative research activity is increasingly encouraged by development agencies, companies and universities (ODELIUS, ABBAD, RESENDE JUNIOR et. al., 2011). For these authors, RG may be an ideal environment for the acquisition and internal and external dissemination of: collective competences, as it provide a joint reflection to members about the difficulties encountered during the research and the searching for solutions to overcome these problems, what is a likely explanation for a superior performance attributed to RG members; technical competencies related to production of knowledge and research processes; and teamwork competencies, that are more interpersonal, necessary for teamwork, and not easily obtained in other contexts.

In addition to contribute to scientific knowledge, RGs influence individual learning (SUTTON, 2010) and form social structures that provide conditions for the development of learning processes (ANTONELLO, 2005). In this way, through the use of learning strategies, it is possible to achieve competencies related to these learning processes, whether formal or informal.

Therefore, it is possible to notice that RGs have the capacity to contribute positively within their members and in organizations they are inserted, making scientific progress possible and achieving other results (ODELIUS and SENA, 2009).

For this study, the definition of RG adopted is: these are environments formed by researchers of different levels of formation, that share financial, material, human resources or even their own knowledge, aiming to generate knowledge, exchange experiences and develop competencies, offering a suitable space for the research process and production of knowledge.

## Scientific collaboration

Collaborative work is not a recent phenomenon, but it has become more visible as collaboration gained space in the academic field.

Vanz and Stumpf (2010) define collaboration as a social process of human interaction that can happen in different ways, at different levels and for different reasons. For the authors, a collaborator can be either the researcher who cooperates in some stage of the research as someone who contributes directly to the research during its entire development.

According to the Directory of Research Groups in Brazil, of the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), the SC has the objectives to “boost knowledge creation and innovation process resulting from exchange of information and, more than anything, to combine groups abilities and efforts in the pursuit of common goals, and it is not necessary that they share facilities”(CNPQ, 2018).

Balancieri, Bovo, Kern et al. (2005) emphasize SC as a cooperative venture involving coordinated effort between participants that have common goals and seek results or products; the authors highlight the contribution of information and communication technologies to establish a SC and to share information between groups. Meanwhile, Leite, Caregnato, Lima et al. (2014) emphasize that these technologies increase the number of SC connections and interfere in the intensity and variety of relationships established between researchers.

In addition, Bulgacov and Verdu (2001) emphasize that the network obtained from SC can be an instrument that have a positive influence over learning and, consequently, over competencies, representing a new organizational logic that, regardless the reasons that guide its formation, has the objective of acquiring new knowledge or to search a bigger involvement with a specific professional community.

In the universities context, some studies indicate that teamwork improves quantity and quality of published articles (ACEDO, BARROSO, ROCHA et al., 2006) and the development of researches involving teams with members from diverse areas lead to create new approaches, reflection forms, practices and expand the ways of solving specific problems (ODELIUS, ABBAD, RESENDE JÚNIOR et al., 2011).

According to Cruz, Coast, Espejo et al. (2010, p. 2), "collaboration between researchers enables sharing of informational and technological resources, experiences and ideas, among other exchanges".

And Odelius, Abbad, Resende Junior et al. (2011) indicate that the RG can be interesting to the group and the individual and requires exchange of information and knowledge, generating the competencies development and learning processes, as well as allowing the establishment of relationships that allow the generation of shared publications. Watanabe, Gomes and Hoffmann (2013) report that this process of publication makes the science a collective endeavor and, thus, increases the interest, in recent decades, over the cooperation between researchers.

Vanz (2013) draws attention to the fact that scientific communities, especially those acting on an experimental basis, are becoming increasingly linked by connections that join researchers and create ever larger and more capable SC structures. In relation to the differentiation between areas, multiple authorship is more common in empirical researches than in theoretical studies (SOARES, SOUZA and MOURA, 2010) and knowledge production presents peculiarities, with preference for different communication vehicles (articles, book chapters and books) and with specific items regarding research problems and motivators for publication, as reported by Leite, Caregnato, Lima et al. (2014).

Milk, Caregnato, Lima et al. (2014) also point out that interdisciplinarity and formation of groups, laboratories, university partnerships and co-authorship are more common in natural sciences than in human sciences.

Based in the presented content, this study adopts the following definition: SC are structures formed by RG whose purpose is a joint action, that shares financial, human, material or knowledge resources, aiming to obtain results related to increase of scientific production, knowledge advancement, development of abilities and learning stimulation.

## METHODOLOGY

This theoretical, empirical, descriptive and qualitative research aims to characterize SC in these areas of knowledge: exact (engineering and Earth science), biological (biology and health science) and humanities (anthropology, political science, education, geography, history, psychology and sociology).

A research made in the Directory of Research Groups of CNPq allowed the identification of group leaders of a Federal University chosen by accessibility that acted in more than one RG and were invited to participate in the research. Among 58 leaders acting in more than a group of the exact sciences, 8 leaders have replied. From 45 leaders in biological area, 5 have participated. And in humanities area, these numbers were respectively: 24 and 8. Interviews were scheduled with leaders who agreed to participate in the research, characterizing it as intentional and by accessibility.

The respondents are characterized for being mostly experienced and receive a productivity scholarship (PS) in research. The majority of the 8 respondents from exact field is man (6) and are doctors for more than 12 years, 1 is graduated for only 1 year and 1 graduated 5 years ago; 2 of them didn't receive PS, 1 of them received PS 2, 3 PS 1B and 2 PS 1A. The groups in this area have between 2 and 28 years (6 having over 10 year) and work in SC with different number of partners, ranging between 1 and 6 groups. They work in engineering (2 in civil engineering and 1 in mechanical engineering), geography (1) geology (3) and chemistry (1).

In the humanities, 4 men and 4 women participated, and they were PhD from 10 to 39 years, 2 of them didn't received PS, 2 of them received PS 2, 1 PS 1C, 1 PS 1B and 2 PS 1A. The groups in this area have between 3 and 22 years and 5 of them have less than 10 years. The number of groups with which they act in SC goes from 1 to 5. They act in anthropology (4), education (2), history (1) and psychology (1). In biological field, 3 women and 2 men participated, they were PhD from 2 to 12 years and only one received P 2. The groups existed from 2 to 9 years and the number of groups with which they act in SC goes from 1 and 3.

Data were collected in two moments: between March and June of 2014 and between April and June of 2015, using a semi-structured script previously elaborated and based on literature review and research objective. They served as a basis for definition of categories of analysis (importance of collaboration, motivation for collaboration; training and interaction processes; aspects that have influence in this process; challenges, problems and difficulties faced and results obtained, including what was learned in this process). The interviews were recorded, and the data were submitted to content analysis (BARDIN, 2011) with transcription

of data into categories established *a priori*. The contents verbalized were analyzed in each one of the categories, initially by students of scientific initiation and later in meetings of an RG, and it was made the identification and grouping of answers with similar meaning. In the presentation of results, some excerpts are transcribed to illustrate data, identifying the respondents with codes, by area of knowledge and number: Biological1 to Biological5; Exact1 to Exact8 and Humanities1 to Humanities8.

## RESULTS AND DISCUSSION

The importance attributed to SC is related to exchanges generated by groups and their members that generate knowledge complementarity and deepen and increase the scientific production; viability for research development when the group has research lines that are still not much explored and/or with few researchers; fulfillment of requirements made by development agencies and resource sharing (i.e. knowledge, financial, material, laboratory).

These are some parts of the interview that illustrate the importance of SC:

*Production of knowledge in technology, information and health education areas is difficult because it's a new subject. For this reason, it has been invested in shared production of scientific articles, resulting from research done in the context of research public tender and "umbrella" projects (Biological2).*

*[...] focus is different in each research group (partners) [...], but always exists a necessity of support from ecology and from biodiversity, so we need to work together (Biological4).*

*Collaboration is necessary for knowledge production, as each group has data collected and information that are important at the moment of research (Biological4).*

SC makes it possible to obtain a greater exchange of information and to improve studies regarding research object and theoretical and methodological basis that is one of the reasons for collaboration. Humanities8 highlights:

*[...] as it is in a network [working with collaboration] there are groups of other places and more contribution because they cover different scenarios, contexts and visions.*

Participants pointed to collaboration as something quite natural and necessary. Box 1 represents excerpts related to performance reason of collaboration, that can be summarized in: knowledge attainment; shared resources (financial, staff, structure and equipment) and knowledge; achieving publication demands and complexity of study; possibility to enjoy advantages of other researchers and groups. These results corroborate a discovery of Francisco (2011) showing that in collaboration, although collaborators are often geographically separated, they seek for knowledge, resources and experiences exchanges.

### Box 1

#### Reasons related to performance in collaboration

Identified aspects	Parts
Meet publishing demands	<i>"To supply what we are not able to do. The publications also motivate partnerships." (Exacts6).</i>
Development, complementarity and shared knowledge	<i>"To establish an international network of collaboration among groups that work with the same subject to share references and research methodologies." (Biological1).</i> <i>"We interact in what we can help, sharing resources and equipment, and they share their knowledge with us." (Exacts5).</i> <i>"I believe one reason would be to be able to serve and share knowledge with other groups." (Exacts5).</i> <i>"We identify that the line of teacher X is very compatible with ours and invite him to aggregate profiles complementing information that is required in our projects." (Exacts7).</i> <i>"The most important is the experience of other group because the analysis are multidisciplinary." (Exacts8).</i> <i>"Expanding knowledge from people with same research interest." (Humanities1).</i> <i>"A partnership with another group gives a theoretical and methodological support to act in the group that I support, since network groups have the same line of research." (Humanities5).</i>



Continue

Identified aspects	Parts
Shared resources	<p>"Infrastructure that we cannot always have in our laboratory, [...] and we find out in collaborators a structure and materials that can be used in our work." (Exacts1).</p> <p>"Structure and to maximize the use of equipment in laboratories. I don't need to have all equipment." (Exacts8).</p>
Extension of research and study complexity	<p>"Major engineering problems also required collaborations with university groups in other states." (Exacts6).</p> <p>"We want to expand this research to other regions and other institutions and participants. Because characteristics of work realized are different; and are now addressing other international regions: Latin America, North America, Europe, Spain, Portugal, France [...] Expand studies." (Humanities8).</p>
Geographical access	<p>"The reason that led to contact with researchers, besides the line of research, was also the proximity of researchers with places where data collection take place." (Biological3).</p>
Elaboration of projects and obtaining funding and development / incentives	<p>"The demand for financial support is crucial for the development research network because in many cases the projects or summons for proposals generate the necessity of specialized personal in a determinate subject." (Exacts1).</p> <p>"The research public tender established a series of requirements: a partnership with a Brazilian institution with a similar course and lines of research. Because of that a partnership with a university in other state was created." (Biological2).</p> <p>"A collaboration network is established according to a tender document or the necessity of research in that moment". (Biological4).</p> <p>"Several national works look for larger teams and development agencies try to approximate older groups and younger groups." (Exacts3).</p> <p>"To have a lot of support from Organization X." (Exacts5).</p> <p>"Researchers obtained support from a German foundation to study relations between South America and Europe and between Brazil and Europe." (Humanities2).</p>
Education	<p>"There is also a lot of training of Human Resources." (Exacts5).</p> <p>"The teacher travels abroad to do a PhD and comes back with a partnership." (Exacts6).</p>
Obtaining results/interest in knowledge production	<p>"There is interest in knowledge production, focusing on generate results." (Exacts1).</p> <p>"There are some groups that even work with different material from ours, but the interest overlaps and we end up collaborating." (Exacts1).</p> <p>"Each area takes care of their part, but without losing the sense of delivering a result." (Exacts2).</p>
Affinity of research lines and/or staff	<p>"From a macro project [...] that originated all great later movements." (Biological2).</p> <p>"[the group] has been working in a collaborative network since the beginning through mine invitations to other researchers who worked on similar lines of research." (Biological3).</p> <p>"The collaboration network is formed from research line, from tender documents and knowledge of congresses, where relationships are created with other researchers in order to address what we are unable to do, exchange materials and information." (Biological4).</p> <p>"Through interested people on the subject and alumni of the leading researcher was created the first network ,that informally had studied a common subject." (Humanities1).</p> <p>"From the moment that the leading researcher identified works that had subjects in common, she invited such researcher to be part of the research group's network." (Humanities4).</p> <p>"The dynamic of the research do not allow it to be individual." (Humanities6).</p> <p>"Common subject of interest." (Humanities7).</p> <p>"Since interests are common, a person who has an opportunity to submit a proposal or a tender document try to expand the project team and calls others." (Exacts1).</p>
Supply gap of qualified personnel	<p>"Basically, from the lack of formation of professionals." (Exacts7).</p>
Share advantages	<p>"Experience, structure and senior groups bring a lot of benefits (Exacts8).</p>

Source: Elaborated by the authors.

Nowadays, working in SC is more frequent and it is becoming increasingly important and necessary, confirming results and perceptions of Vanz and Stumpf (2010), Watanabe, Gomes and Hoffmann (2013) and Soares, Souza and Moura (2010), that address in their theoretical references the structures of research departments, expansion of vehicles of scientific production dissemination, increase in availability of data processing tools, knowledge development patterns and SCs have changed and diversified over time.

The *reason for this performance in SC* relates to: viability of perform research, by affinity/proximity of research lines, by necessity of complementary knowledge (theoretical and methodological) or resources; greater research complexity, new subjects studied and difficulty to keep up with current speed and volume of knowledge production requiring more researchers and teamwork; recognition that working together leads to better research results and knowledge advancement; impossibility of develop research and achieve results working in an individual way; requirement established in public tender documents (performance in partnerships, necessity of data collection in different regions, sharing equipments, need for optimization of resource use and leverage of results). Vanz and Stumpf (2010), Ramos and Velho (2013) and Santin, Vanz and Stumpf (2016) indicate that one of the main reasons for SC formation is interdisciplinary science and Soares, Souza and Moura (2010, p. 529) identified as the main reasons for SC: “specialization, work sharing, increase of experimental research, data availability, growth of statistical sophistication, access to methods, equipment, specific competencies and financing”. From these topics, work sharing was not an aspect addressed by participants in this study.

Burton Clark (1998) apud Leite, Caregnato, Lima et al. (2014) also identified that SCs are motivated by researchers who have common goals and share similar paradigms, methodologies, and hypotheses, using collective communication strategies to reduce boundaries among members of a group network. The time factor is recognized by Santin, Vanz and Stumpf (2016) as necessary for the consolidation of collaborations, as it is highlighted by part of the interviewed.

In relation to needing to combine resources and *expertise* to attend promotion politics of SC, the results corroborate studies of Cruz, Costa, Espejo et al. (2010) and Ramos and Velho (2013). In addition to these reasons, the literature emphasizes the search for research excellence, the reductions of the time dispensed and the possibility of errors in the researches (THE ROYAL SOCIETY, 2011; VANZ and STUMPF, 2010); have third-party assessment, and personal issues, such as the appreciation for working in partnership (VANZ and STUMPF, 2010).

To *work with collaboration*, in order to meet demands of tender documents, partnership with organizations, projects realization and complementary knowledge to generate scientific productions, the criteria for choosing partners by researcher(s) involved were: previously established contacts with other people who shared personal and/or academic interests; and/or identification of researchers considered a reference in the knowledge area. Work in the projects defense, dissertations and theses; coexistence during the accomplishment of masters and/or doctorate; relationship with counselor or counselors; contact in congresses and seminars; and to have worked together on previous projects were situations mentioned as criteria for establishing partnerships.

Some parts that illustrate these subjects are:

*The partnership was formed due to an invitation from the leader to our group to participate in the national project proposal* (Biological5).

*Existing partnership through personal contacts* (Exacts6).

*By knowing the person before. I've meet a lot of great people [where I graduated] that I still have a good relationship, that I know they work well [...] Collaborations outside Brazil happened because my wife and I worked outside Brazil in laboratories and we always work with those we know* (Exacts8).

*[...] the leader researcher contacted (symposiums, meetings etc.) with other great researchers [...] From interchanges, the group initiated to stablish an international network. Initially the lead researcher contacted a few researchers from Germany. Later, when the time passed, other countries also showed interest* (Humanities1).

*The partnerships [...] happened when I was on University. I had histories of similar graduation with people who are part of the network [...] Contacts established were resumed in events and scientific congresses* (Exacts1).



*The partnership started before the group, several teachers did doctorate together, it was easy to maintain that after graduating (Exacts3).*

*[...] others were my students, or I was in their evaluation board (Exacts4)*

*I became aware of the person's existence through publications and I went after people who knew who I was looking for and found out their contact (Exacts4).*

*The idea was to aggregate people who had similar research identities to strengthen the knowledge field and not be working in parallel, generating a good partnership that would add efforts, producing aggregate and non-repeated works (Humanities3).*

The *interaction dynamic* between participants of SC covers meetings, seminars, organization of events, production of books and articles; and use of technology (*e-mail*; *Skype*<sup>®</sup>; other electronic media) to overcome geographical distances. Vanz and Stumpf (2010) explain that advances in technology and communication facilitate the interaction of researchers and collaboration, contributing to the strengthening of collaborations for knowledge production.

This result demonstrates the importance of communication media to maintain a continuous exchange of information, principally in collaborations constituted by members of several areas, domiciled in other cities and even other countries, a fact that makes impossible for all members to attend to face-to-face meetings. Information technology tools are also used by some groups by the valuation of this resource. Balancieri, Bovo, Kern et al. (2005) emphasize the importance of information technology contributions to SC, especially in situations where partners are geographically dispersed.

Participation in events such as evaluation boards, congresses and other events were identified as extremely important in order to facilitate the formation of networking, that is looking for new contacts that may be important in future projects and/or researches. Face-to-face meetings were highlighted as important, especially at the beginning of partnerships, to ensure building bonds and trust relationships.

The availability of resources for conducting face-to-face meetings, through proposals or other resources, was also highlighted by some leaders.

In relation to *type and regularity of interactions*, there was a variability as a result of project and group characteristics and identified needs. They could be daily, weekly, monthly or variable and were performed with all or part of participants of groups or members of the SC, a similar result to the one of Odelius and Sena (2009). The previous acquaintance and proximity of SC participants are highlighted as an important factor for consolidation of partnerships (FAFCHAMPS, VAN DER LEIJ and GOYAL, 2006).

Some *challenges, difficulties and problems* pointed to work in SC were different for participants of knowledge areas investigated. It is important to highlight that data is related to the reality of groups interviewed and not necessarily to all groups. Members of biological areas emphasize: incorporation of new members into groups (undergraduate and graduate students and research professors); expansion of SC, exchange of dialogues and aspects related to the knowledge production process (cultural issues, uses and customs of the area); and context of action, according to Biological3:

*The great challenges are linked to academic issues. In other words, it is difficult for a researcher who leaves his own space as a researcher to have a relation with another researcher from another university to generate knowledge, share it, work together and the difficulty of transferring it. Therefore, every knowledge construction process is different when working with a researcher from another university and another research group (Biological3).*

In addition, making the theme interesting for all participants of the group is a challenge, when the group is multidisciplinary and integrates researchers with different experience and formation; concatenate/reconcile different points of view, legal requirements and government authorizations; and manage people.

The negotiation with institutions to carry out researches and meet bureaucratic processes were highlighted as responsible for making the research processes slow and time consuming and one of the exact groups highlighted the necessity of quick adaptation to institutions/contexts with different real problems. Still in the exact area, *challenges, problems and difficulties mentioned* had been related to: management of deadlines and resources; availability of financial resources for exchanges

among members of SC; data integration; interaction and contribution to society; and productivism (focus on quantity of publications), as well as geographic distance that makes relationship between researchers more complex, demanding greater care in aspects related to communication to ensure an assertive understanding of messages and to avoid the occurrence of noises, being more difficult to strengthen personal relationship, different than situation which researchers are close. Lack of proximity makes essential to manage interactions. Katz and Martir (1997), Ramos and Velho (2013) and Fafchamps, Van Der Leij and Goyal (2006) emphasize the necessity of mutual knowledge and previous contacts between researchers so that SC can become viable, a similar opinion of some of the interviewed. In a similar study Odelius, Abbad, Resende Júnior et al. (2011) found a compatible result, especially related to the difficulty of obtaining financial and material resources for the development of group's activities and a lack of encouragement to research.

The size of the SC team was identified as a challenge, because the bigger it gets, more complex it becomes: administration of resources and people; consensus of opinions among members of different areas (for resource allocation, definition of publications, data interpretation and problem solutions); and meeting and discussion of results found in each group. In addition, there is the challenge of managing distribution logistics of financial resources and materials among members of the SC that has to be an adequate division to avoid a deficit in equipment, samples, materials and financial resources important for the research progress.

When there are groups of other countries or regions that participate in the SC, other factors make it difficult: diversity in groups dynamics; cultural differences; specificities regarding demands for attendance of tender documents and accounting; time zone; differences in school calendars; and vacation. In the human area, challenges pointed out were: effectively making the research; the group to be productive; keep the project active and funded over time; demonstrate credibility of what is being done; and time management of SC participants.

One problem pointed out by a participant of the human area is that researchers do not always fulfill their responsibilities, especially when working from far away and there is also a serious problem that researchers leave groups without leaving anyone to replace them. Fafchamps, Van Der Leij and Goyal (2006) indicate that co-authoring (as in SC) involves a number of risks: having insufficient information related to real competencies of the potential co-author; co-author does not have complementarities necessary to work as a team; there are disagreements about how to conduct the research or perceptions of injustice regarding distribution of workload; non-compliance of work agreement made between researchers.

Some challenges pointed out in this area are related to research development characteristics, such as participants given up during research, which sometimes makes the project unviable, and in case of action research, make the participants believe that they are capable to do research, to contribute to theoretical production and to achieve repercussion in daily practices.

Leaders of human area have highlighted the challenge of keeping the group alive, regardless of the flow of researchers and leaders, as well as studies in specific topics which the research process is complex and time consuming and there is no valorization by development agencies, since tender documents are few and directed to other areas or themes. This makes the subject less competitive compared to other knowledge areas.

Three challenges pointed out by exact and biological areas are related to interaction with society: the expansion of SC and integration with society, due to difficulty of identifying possible contributions of the academy to the solution of society problems and how this contribution can be done; and the necessity of a greater dialogue between academic and popular knowledge.

Some challenges and difficulties are common to the areas: researchers have to deal with work overload; obtaining resources; location issues (geographic distance); time; languages and individual aspects, such as lack of motivation to be in a group and adverse attitudes towards participation and collaborative action, often associated with cultural issues, such as relying on friendship to postpone activities or complete them only when the deadline is at the end.

Geographic distance constrains communication between SC participants, hindering the interaction and blocking the discussion process of research results analysis and the preparation of reports in partnership. In your turn, time makes SC harder because of: its scarcity, that demand organization of available time and administration of schedule of development of activities: logistic of agenda conciliation; as well as necessity of time to know and to establish a relationship.

Regarding languages, difficulty is related to bibliography access and to interaction process. While working with foreign groups that speak another language, the communication is damaged as not all members, leaders and researchers speak the language, and this may compromise the work development and the final result obtained. The difficulty of interaction due to cultural and language issues, as well as geographical distance, is similar to what was noticed by Sidone, Haddad and Mena-Chalco (2016).

There are also other difficulties directly associated to the joint collaboration process that include establishing a partnership, building the research together and sharing results:

*There is often the difficulty for a researcher to openly accept contributions of other researchers and realize that the work is not only his, but it is a group's work. With distance there is a lack of a bigger relationship between researchers. When people are close, it is easier to have the work done. That's why meetings are important. (Humanities3).*

*Make a proposal to unknown groups is harder, because there is no trust. It is necessary to establish bonds, try to establish a contact, send a student and then start. (Exacts8).*

Still talking about this aspect and related to multidisciplinary, there is the difficulty to define vehicles for results dissemination, due to classification differences of periodicals, and order of authorship, since not always criteria among areas and countries are similar. As discussed earlier, these aspects corroborate the studies of Fafchamps, Van Der Leij and Goyal (2006) and Katz and Martin (1997) that highlight that similar aspects to these ones may be reasons for the researcher deciding to develop his work individually.

Despite differences pointed out in each one of the researched areas about challenges and problems of SC, it's impossible to affirm that they are characteristics of the areas, new studies are necessary for this verification.

Regarding *facilitators* to work in SC, results indicate information technology as a determinant factor for communication because it enables sharing of information by e-mails and knowledge management by cloud storage, similar to the result found by Francisco (2011).

However, although information technology is a channel used to hold meetings, conferences, interviews with researchers in another state or country, geographic proximity is presented as a factor facilitating communication, resource allocation, scheduling meeting and infrastructure sharing.

Other aspects, such as common interests, motivation and engagement, contribute to ease interpersonal relationship and the achievement of a desired result. Ramos and Velho (2006) emphasize the importance of intellectual affinity between SC partners and Fafchamps, Van Der Leij and Goyal (2006) highlight the importance of personal relationships established between researchers and that researchers consider that they have better expectations by working in SC than working alone.

Some researchers pointed out that having funding or sponsorship from a development agency, educational institution and/or private company is determinant to work in SC and one of them emphasized the importance of prior negotiation of roles of the project members, related to activities and results to be achieved and to aspects related to authorship (who and in which order authors will be included) and publication channels to be used.

A synthesis of facilitating aspects for SC activity embrace: use of information technology; face-to-face meetings; common interests, motivation and engagement; availability to share knowledge and experience to work in SC; prior agreement on aspects related to SC; availability of resources; and geographical distance. As explained previously, these details are similar to literature.

There has been an overlap in challenges, problems, difficulties and facilitators and, in several situations, the presence or absence of some conditions determinates how that aspect will be perceived.

The main results of working in SC include the apprehension of specific knowledge in the research field (scientific production and related topics) and procedures related to research development (bibliographic review, sample definition, instrument validation and data analysis). Therefore, there is a better use of the SC member's expertise and resources.

Moreover, other gains happen: higher knowledge production; new discoveries of research objects, easier publishing of books, publication of higher quality articles, learning booklets; prize and awards; realization and participation in a greater number of conferences through networking previously established with people in a national / international level; extension courses and projects in society; publication of journals; and many of them are directly related to creation, sharing and dissemination of knowledge. In literature, Soares, Souza and Moura (2010, p. 529) emphasize as benefits obtained by SC: "make great researches possible, save effort and time, increase productivity, be placed in a reference group, exchange work between teachers and students and raise research quality." In their turn, the quality of articles are mentioned by Acedo, Barroso, Rocha et al. (2006)

and Goran Melin (2000) apud Soares, Souza and Moura (2010), while other authors point out that SC has as a characteristic the achievement of results that go beyond publications, such as joint organization of conferences and joint development of research projects (SIDONE, HADDAD and MENA-CHALCO, 2016) and informal exchange of ideas, materials and information until the joint definition of the research problem, treatment and research methods, perspectives of interpretation and result analysis, and expanded communication, materialized as scientific publications (LEITE, CAREGNATO, LIMA et al., 2014; RAMOS and VELHO, 2013).

Another feature is the visibility gained by project done in SC. In addition to the group being known by government agencies, private companies and educational institutions in foreign countries, there is greater visibility among students, who began to become more interested in integrating the group, promoting quantitative and qualitative expansion of the group with the knowledge expansion that each participant can add. Another result is receive new invitations to expand collaboration. The visibility is emphasized by Vanz and Stumpf (2010) as one of the reasons why SC is established.

Data related to *learning from participating in SC* covered information related to content, processes and learning source.

The learned contents are presented in Box 2.

## Box 2

### Content learned from participating in SC

What is learned	Parts
Competencies	<p><i>"We had to learn how to manage projects. The bureaucratic part of achieving consensus regarding what is priority in investing in the project. (Exacts1).</i></p> <p><i>"I think that is understand about other people rhythm and style. The collaboration allows us to see that the neighbor's grass is not so green [...] it helps to learn about equipment and methodologies. I learned different ways to guide students. To simplify things, without losing their quality." (Exacts6).</i></p> <p><i>"Listen to colleagues, understand points of views, take great advantage of what they have as personal and research experience and their policy of sharing data. How we can influence in the formation of our students." (Exacts7).</i></p> <p><i>"A lot of things, as a network is really multidisciplinary makes me think accurately about the problem. Seeing other people questioning methodologies helped me to improve as a researcher." (Exacts8).</i></p> <p><i>"To be patient. Knowledge also. To learn how to deal with large groups." (Exacts5).</i></p>
Interpersonal relations	<p><i>"The team is bigger and I found it more difficult to distribute resources, organize samples, gather results and manage the team because it contained different laboratories in different institutions." (Exacts1).</i></p> <p><i>"Dealing with lack of participation and individual posture that characterizes the culture of several researchers." (Exacts2).</i></p> <p><i>"I learned to work with diversity, exchange experiences and have a broader look." (Biological1).</i></p>
Collaborative work	<p><i>"I learned to work in favor of the knowledge production in a cooperative way rather than in a dispute." (Biological1).</i></p> <p><i>"I learned to seek for national potentialities and to value them. In another words, to give prestige to national researchers. Moreover, I learned to deal with differences between cultural factors." (Biological2).</i></p>
New discoveries	<p><i>"Proper scientific results, many areas that were totally unknown to the group, collaboration made possible to be known." (Exacts1).</i></p>
Better group management	<p><i>"Allow all researchers to discuss under equal conditions, regardless subject and role played in the group." (Humanities1).</i></p> <p><i>"I learned that it is possible to manage people in the science field, especially in a fragile area in Brazil that is information, communication, education and health technologies." (Biological2).</i></p>
Visibility	<p><i>"The learning process is rich. I learned that networking is powerful as actions take higher dimensions in producing results. Isolated actions maybe did not get as much repercussion as they have in a network." (Biological5).</i></p>

Source: Elaborated by the authors.

The learning process happened by: experience (personal and others); graduation in training and courses; problem solving, errors and reflection processes; interaction with people, exchange of ideas and a conflict between divergent points of view; readings; participation in seminars and congresses organized by SC partners; while realizing activities (researches, preparation and monitoring of project, their respective documentation and accounting). Therefore, learning by living, through exchanges between professionals with different forms of organization of knowledge production and as a result of interaction with senior

researchers, students and staff that provide services to the university. Specific characteristics of senior researchers were mentioned as important to this process: competence, patience, common sense and pondering.

Haythornthwaite (2006) quoted by Odelius and Sena (2009) shows that most members of a collaboration network are learning something from someone rather than just the process of making a research. In relation to what was learned, the development of technical competencies regarding knowledge production of research processes, as well as teamwork competencies, result similar to those of Odelius, Abbad, Resende Junior et al. (2011).

Du (2009) says that collaborative action in RG leads to improved practices, new opportunities for reflection, as Exacts 6 emphasize ("re-evaluate local methodologies and look at other ways of doing things") and Exacts8 ("seeing other people questioning methodologies helped me to improve as a researcher").

For the effective operation of an RG in SC, participants reported having to learn contents related to project management, allocation and resource distribution, interpersonal relations (motivation, leadership, coordination), selection and planning. In addition to a holistic knowledge of other knowledge areas to be able to quickly solve problems that are often outside the scope of their expertise.

It was also highlighted that is necessary to prepare SC participants to deal with differences that characterize the areas (from familiarization with concepts to diversity of methods and procedures) to be able to obtain and share knowledge, in order to generate results more accurate and efficient and increase criticism and analysis of results.

Ramos and Velho (2013) emphasize that is necessary to develop new competences for international SC activity that are similar to competences indicated by participants in SC: negotiation ability; coordination of people and resources; management of research process; entrepreneurship; problem solving; intellectual appropriation and social communication of results.

Exchange of information, knowledge sharing and transfer of experience allow new discoveries for licenses, reaching results that had not been achieved previously and discovering new places for data collection.

Illeris (2004) emphasizes similar aspects when he affirms that learning at work is influenced by the way the work context is organized (content of people's work, autonomy degree, possibilities of social interaction, etc.) and by participation in practical, cultural and/or politic community work.

The study made it possible to identify the complexity of establishment and maintenance of SC, resulting from the interrelation of the investigated aspects: characteristics of the areas; training motives; interaction dynamics; challenges, problems, difficulties and facilitators of SC.

Some aspects were common to the different RGs interviewed. Interaction, communication and time, in addition to what has already been highlighted, have a fundamental role in the process because stablishing a SC demands trust among its members, a situation that is built up over time.

The following parts illustrate the dynamic and procedural nature of SC, similar to reported in literature by, for example, Santin, Vanz and Stumpf (2016):

*Although the communication has advanced, it is still difficult because it depends on other party that is on the other side and their agendas (Biological5).*

*As time passed, I learned. Demands and needs made me gradually learn how to work with research in this area (Biological4).*

*Time is a factor that makes it difficult, because in knowledge production, it takes time for people to get to know each other and establish a relationship in order to be able to produce knowledge that is close to reality, and often time for projects is not enough for this becoming natural and healthy (Biological1).*

*As group's visibility increases, in the past we were going after funding, today a lot of companies have contacted the group requesting help for their daily problems. The knowledge developed by the network is being applied to real problems and we have to adapt quickly to contexts of companies' problems that are looking for us (Exacts3).*



The importance of incentive and preparation to work in SC is emphasized by visibility and attractiveness of groups that work in SC and by this speech:

*Even without a direct encouragement by the government agencies for participation in collaborative networks, if the person is willing to share the knowledge, excited and thinking about the development of the area, the generation of results will probably be better due to the collaboration and commitment. This indirectly increases the evaluation by development agencies. This culture of people being more open and valuing to be part of a group should be more valued by organizations that evaluate us, they should evaluate more the participation of that colleague in the area, not only the product generated (Exact2).*

These aspects, associated with the necessity of researchers' willingness to work in SC are highlighted by Katz and Martin (1997) and Fafchamps, Van Der Leij and Goyal (2006). These authors also acknowledge the importance of preparation and performance of senior researchers at SCs, as it has been identified in this research.

The results of this research, as it can be seen along the text, are similar to the results and assumptions indicated in studies and previous researches related to the theme. However, some differences were identified:

- a) Among aspects addressed in literature that were not mentioned by participants are: 1) seeking research excellence and reductions in time and in the possibility of errors in surveys (THE ROYAL SOCIETY, 2011; VANZ and STUMPF, 2010); 2) relying on third-party evaluation and personal issues, such as appreciation for working in partnership (VANZ and STUMPF, 2010).
- b) Among the aspects identified in this research and not addressed in literature are: 1) difficulties in development and maintenance of SC (ex.: effectively perform the research; group becoming productive; keeping the project alive and with funding over time; demonstrate credibility of what is being made; management of SC participant's schedule); 2) necessity of preparation of SC participants to deal with the differences that characterize the areas (from familiarization with concepts to diversity of methods and procedures).
- c) Challenges related to: 1) the group continuing to exist, regardless flow of researchers and leaders; 2) studies on specific topics that have a complex research process, are time consuming and have no appreciation from development agencies, since there are few proposals and they are directed to other areas or themes; 3) interaction with society because of difficulty in identifying possible contributions to the academy to solve society's problems and how this contribution can be made, in addition to the necessity of more dialogue between academic and popular knowledge; 4) deal with differences arising from specifics and requirements of development agencies in different countries, time zones and with different school calendars and vacations in international SC.
- d) A prior agreement on aspects related to SC is important like roles of different members of projects, activities and results to be achieved, aspects related to authorship (who and in which order authors will be included) and publication channels that will be used.
- e) Identification of learning methods during SC and competences helps a better group management.
- f) Details of aspects mentioned as difficulties in literature and in SC as geographic distance and time.



## CONCLUSION

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It can be stated that the objective of characterizing a SC in the perspective of RG leaders from different knowledge areas has been achieved. It was identified that leaders realized the necessity of partnerships and in this way established partnerships, voluntarily or induced by tender documents. Research processes and knowledge production in general are the same in groups of same area and events held in the knowledge area and close research lines are the main aspects that contribute to formation of partnerships, beside previous acquaintance of members.

SC work originates networks formed by researchers who have a common and/or complementary subject, based on pre-established contacts or search for a specific expertise, aiming to achieve the research viability and knowledge demands.

The intention of SC work is associated with something natural and necessary, principally because of: interest in sharing financial resources and equipment; expand studies and research, diversification of theoretical and methodological perspectives, obtain more knowledge about the subject and use and exchange of knowledge and experience with other SC members.

SC face challenges, problems and difficulties such as: multidisciplinary; insertion and maintenance of members in groups (undergraduate students, master's and doctorate and research professors); obtaining resources; geographical distances; interaction and communication processes (including language); time and work overload; meet administrative bureaucratic processes and legislative demands; management of deadlines; differences and individual characteristics; cultural aspects.

The main results are: better utilization of resources; quality improvement; and expanding production and knowledge dissemination.

In addition to increasing knowledge about subjects studied, there are numerous aspects learned: work with diversity and collaboration; valorize national researchers; plan and record activities of the group; humility; and deal requirements of Brazilian laws and government.

The fact that it is not possible to generalize results of researched areas is one of the limitations of this study, due to the small number of groups interviewed in each knowledge areas and, as a result of data being collected by interviews, it is possible that other aspects may not have been remembered at the time of data collection.

This study contributes to science by corroborating previous discoveries and by adding new information about SC as indicated in the data discussion. To continue this research, it is recommended to realize studies using other methodological strategies that would allow: 1) generalization of results; 2) collecting information from other participants besides RG leader; and the verification of differences identified in this study as characteristics or not of knowledge areas.

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