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Factors influencing the effectiveness of group interactions among international and interdisciplinary early-career researchers working toward environmental sustainability in climate change

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Abstract
Global warming is a current problem that needs to be addressed by collaborating with researchers from different disciplines and expertise. There is a concern about training the next generation of scientists to holistically address climate change. One way to address this concern is gathering researchers to promote collaboration, as a critical aspect of the scientific perspective. This study focused on the interactions among 119 early career researchers from different disciplines and countries attending the São Paulo School of Advanced Science on Climate Change 2017 in Brazil. The aim of this research case study was to identify factors and social dynamics influencing the effective generation of collaborative networks. First, social perceptions were assessed to expose factors influencing the open exchange of knowledge and dynamics among the new researchers. Second, the occurrence of interdisciplinary and intercultural interactions was evaluated using social network analysis. Using the qualitative and quantitative outcomes, perceived indicators related to barriers (e.g., language and background) and drivers (e.g., gender and age) were linked to the structure of two social networks analyzed: workplace/studyplace, and professions. Social network analysis showed that although the participants aggregated challenging the goal of collaborative networks, they actively sought interdisciplinary approaches. Based on detected barriers, future events organizers searching for an interdisciplinary climate change approach are encouraged to actively overcome these limitations by taking into account the culture, beliefs, and conceptualization aspects at a group level without overlooking individual preferences.

Keywords Sustainable science · Interdisciplinary approaches · Climate change · Social network

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1 Introduction

The emergence of "Sustainability Science," a new field of research, has its origin in the concept of sustainable development proposed by the World Commission on Environment and Development (Butlin, 1989). Addressing sustainability from a healthy coexistence with economy and the environment (Komiyama & Takeuchi, 2006) is a complex task since it involves different levels and systems of cooperation, e.g., global, social, and human (Lang et al., 2012). Sustainability science therefore adopts a comprehensive approach to identify problems and perspectives involving the balanced interplay between different levels and suggesting holistic solutions. Therefore, the building of academic interdisciplinary teams and the addressing of research to solve specific problems were proposed (Kueffer et al., 2012).

Sustainability science can holistically address global warming (Allen et al., 2019; Masson-Delmotte et al., 2018) which stems from the interaction between the global and social-human systems affecting human survival (Lang et al., 2012). Addressing global warming requires the needs to: 1) better understand the natural processes involved and their impact on climate from a natural sciences perspective (Eyring et al., 2016; Telteu et al., 2021); 2) comprehend how these natural processes affect human population and how they can adapt to them (Carmin et al., 2015; Fankhauser, 2017); and 3) develop technical and engineering skills to increase human resilience and reduce greenhouse emissions (Rosen, 2012). Addressing these problems requires a new paradigm of interdisciplinary collaboration which incorporates tools, techniques, and insights from across the social, natural, and engineering sciences (Gaziulusoy et al., 2016; Hein et al., 2018) and the need to train the next generation of climate change researchers.

The interdisciplinary approach, particularly within a heterogeneous group of researchers, enhances knowledge sharing, communication, critical thinking, problem solving, and creativity (National Research Council, 2014). However, particular challenges are faced by early to mid-career scientists in achieving interdisciplinary work (Hein et al., 2018). In order to avoid these challenges, some suggestions were made for encouraging interdisciplinary work such as prioritizing funding of interdisciplinary seed grants, fellowships, and junior faculty networks, and motivating interdisciplinary teamwork and communication training/interdepartmental symposia. Researchers also found an opportunity to work together to collaboratively discuss and share knowledge (Bridle et al., 2013; Lyall et al., 2013) in scientific conferences, seminars, workshops, and summer schools. During these gatherings, participants are expected to acquire different tools and skills including knowledge, contacts, experiences or discussions to perform interdisciplinary work at multi-scale levels. However, these gatherings may not be enough for inducing interdisciplinary research because of the emergence of factors which influence group interactions. Knowing and understanding these factors can be interesting to overcome them.

This paper focuses on a case study research based on the participation of 119 new climate change researchers in the São Paulo School of Advanced Science on Climate Change 2017-SPSASCC: Scientific Basis, Adaptation, Vulnerability and Mitigation (SPSASCC-17) to understand the role of activities in strengthening the connections among climate change new scientists. The aim of this study was to detect factors and social dynamics influencing the effectiveness of group interactions among international and interdisciplinary new researchers working toward environmental sustainability in climate change. First, social perceptions were assessed to expose factors influencing the open exchange of knowledge and dynamics among the new researchers, exploring whether these factors were initial or from previous biases. Second, the occurrence of interdisciplinary and intercultural interactions was evaluated using social network analysis. Based on the assumption of an open exchange of ideas among the participants, the working hypotheses were: 1) the absence of perceived and manifested barriers for the interaction and 2) social networks with a high degree (connections), without communities (groupings), and without connection among disciplines and origins.

Identifying and sharing some of the challenges constraining the free exchange of ideas provide useful insights for organizations to cope with the interdisciplinary approach during academic events focused on climate change research. Regarding this approach, this research group is a successful example since even four years after participating in the SPSASCC-17 and is still working diligently on this and other projects related to climate change. Currently, the group has an interdisciplinary network with colleagues from around the world who share knowledge and information on common interests.

2 Materials and methods

2.1 Research setting

The study was conducted with participants at SPSASCC 2017[1] (from now on SPSASCC-17) held in 2017 from July 3 to 15 in São Paulo, Brazil. The course objectives were: a) to contribute to the training of graduate students in the area of climate change, b) to foster the exchange of knowledge from many disciplines and sectors, among the participants and with school lectures and organizers, and c) to promote the development of collaborative networks to gather a critical mass of early career researchers interested in climatic change and its impacts on ecosystems and society.

At SPSASCC-17, a multi-disciplinary academic group comprising 119 new professionals representing different stages of training (including masters, PhD, postdoc-students and other new researchers) from 30 different countries were present. The two weeks' course involved engaging in small groups activities, poster sessions, lunch and dinner time, field trips, and workshops. At SPSASCC-17, about half (50%) of the participants came from Brazil and constituted adequate women representation to ensure gender equality per the organizers objectives. Details of the characteristics of the participants regarding their country of residence and maximum degree of study are shown in Appendix 1 and in INCLINE (2017b).

[1] [1]Organized by the INterdisciplinary CLimate INvestigation cEnter (INCLINE) and the Inter-American Institute for Global Change Research (IAI). Sponsored by the São Paulo Research Foundation (FAPESP), Pró Reitoria de Pesquisa/University of São Paulo (PRP/USP), IAI and Santander. The IAI is an intergovernmental organization established by 19 countries of the Americas that pursue the principles of scientific excellence, multinational collaboration in global change research, and the full and open exchange of scientific information (INCLINE 2017a).

3 Research design and data collection

Both primary and secondary data sources were used in this study. In order to ensure the study was pragmatically conducted, an inclusive approach was adopted where all participants at the course were selected as study respondents for the primary data source. This was done to support awareness creation of the study, improve the quality and relevance of the assessment data as well as reduce subjectivity in the selection process (Raemaekers & Sowman, 2015; Tiani et al., 2015). As well, it was incumbent to draw data from multiple sources at the school in order to capture the case under study in its complexity and entirety (Yazan, 2015).

Due to time constraints, a semi-structured online survey was designed during the school in July 2017, using the free Google Forms Software (Appendix 2). The survey was sent via e-mail to all the participants of the summer school during the last day of the event. Authors of this paper were exempted from the survey to avoid bias in the data collection. In addition, the project was orally explained to all SPSASCC-17 members, who were invited to respond to the anonymous survey. Oral permission was obtained from the organizers of the school, for clearance before the study commenced. Yin (2009) perspective was followed, as the study combined quantitative and qualitative evidence. The survey consisted of 12 questions, half of which were used to characterize the sample population. The other half specifically evaluated the interactions among the SPSASCC-17 participants and the perceived factors affecting the interactions.

Information about background, gender, origin, profession, and experience of the participants was consulted. Participants were asked about who they interacted with (country of workplace and/or studyplace, profession), to show the type of interactions, and to share their expectations about the interactions and moments where the strongest interactions were experienced during the school were also asked (Appendix 2). Based on Eisenberg and Pellmar (2000), who proposed categories of barriers as attitude, communication as well as others like academic structure, funding and career development to overcome for achieving interdisciplinary work, and the interdisciplinary work of this group of participating observers, six factors were proposed in the query as barriers for the interaction; the "others" option was available to freely complete with non-proposed perceptions (Appendix 2). Direct observations and participant observation by the research group were also adopted. The estimated time for completing the on-line questionnaire was between 5 and 10 min.

For the secondary data, this research made use of different evidence, thus documentation and archival records from INCLINE and existing scientific literature.

3.1 Data analysis

3.1.1 Initial descriptive analyses and categorizations

During the data analysis process, survey transcripts and notes were studied. In order to assess whether the universe of study (the whole school) was represented by the survey (sample population), first the school was characterized based on socio-demographic aspects of interest, using the SPSASCC-17 database (INCLINE, 2017). Then, the information obtained from the sample population was compared with the socio-demographic characteristics of the universe of study, through descriptive analysis. We proposed to test “Language,” “Culture,” “Gender,” “Personal,” “Age,” and “Background” as possible factors affecting the exchange among the participants. The verification of this assumption was made by asking to "Select the barriers that reduced the effective communication with other participants during the SPSASCC-17." With anticipated possible factors other than the ones considered in the survey, participants also had the option to choose the field “Others,” to freely fill in their perceptions. The responses were analyzed with descriptive statistics as frequency analyses, and the figure was done using R core Team (2020). Responses to the semi-structured survey allowed to establish a categorization for workplace and studyplace (6 groups: Africa, Central America, South America, North America, Asia, and Europe) and for professions (10 groups: Natural Sciences, Engineering, Social Sciences, Health Sciences, Agronomy, Meteorologist, Politics and Diplomacy, Chemistry, Math and Economy), to be used in the social network analysis. From now on "workplace/studyplace" will be used to refer to the country of work and/or study declared by the participants.

3.1.2 Social network analysis

Social network analysis (SNA) is a descriptive tool, used to evaluate relationships in a study group (Freeman, 1978; Newman, 2012; Scott, 2011), abstracting the most relevant features of a case-study and representing them and their connections as a network (Borgatti et al., 2009; Carrington et al., 2005). The SNA allows mapping and measuring different properties associated with the underlying social architecture in an organization where individuals connect to each other. In SNA, the subjects of the study are represented by nodes, while the relationships between them are the links (Hanneman & Riddle, 2005), representing the interactions. In this way, from relational data (e.g., links or connections that relate one node to another) coded in a matrix, the graph theory provides a formal language to describe networks and their characteristics, translating matrix data into concepts and formal theorems that may be directly related to relevant characteristics of social networks.

In this research, SNA was run to evaluate the dynamic of interactions among the survey participants, developed in “real scenario” of the SPSASCC-17. The SNA and the graphs generated from the matrix associated with the survey data set were performed using the IGraph package (Csardi & Nepusz, 2006). Two networks were constructed, one with nodes representing the 6 groups from work/school data, and another one with nodes representing the 10 groups from professions. Inside each network, the interactions that the participants expressed to have during the school were considered as a link among nodes of the same type (work/school place or professions). If more than one group is shared, the link is weighted accordingly.

In order to understand the connections during the SPSASCC-17, the dynamic of links among nodes of the same type as a function of the kind of interaction built during the school was characterized. These connections can be established through the articulation of several interrelated but different aspects of the level of integration of the network. Social integration during the advanced school was interpreted globally through indicators as “density,” “clustering” or “modularity.” The density index represents the connections between the interactions generated in the "real scenario" and those that could have been made in the "hypothetical scenario." A higher density implies a very articulated network, while a low density implies isolation of the participants; this integrity can be also described through the transitivity (clustering) index. Modularity denotes the appearance of distinctive subgroups (communities) in the social network. Highly distinctive subgroups indicate greater segregation or a poorly integrated network, while less distinctive subgroups account for a more integrated network (Gest, 2016).

Table 1 Concepts established in this work

Concept	Definition
Product	Collaboration actions (e.g., participation in publications as co-authors, contacts for obtaining financial funds, contacts for advice in their research or formulation of new joint projects)
Hypothetical scenario	Conceptually, supports the maximum number of interactions among participants of the SPSASCC-17
Real scenario	Supports the different types of interactions achieved among the participants during the school, oriented to generate products
Productivity	Products generated from effective interactions during SPSASCC-17

When analyzing within groups, local measures centered on the nodes can also be indicative of social integration, through indicators as “degree” (in and out) and “betweenness.” The degree is an evaluation of measures of centrality of the nodes (e.g., measure based on how connected a node is within their local environment), as well as their degree of entry (IN degree) and their degree of exit (OUT-degree) for the case of directed networks, and provides information about the level of network integration from the average of these measures. The betweenness measures how important a given node is in establishing bridges between other nodes in the network. The removal of a node of very high betweenness could split the network into two separate networks. It will reflect intercultural connections or interdisciplinary work, respectively.

Network analysis can be performed on unbalanced populations. However, the case of Brazil represented a hard imbalance, so a special procedure was carried out to detect its weight in the performed SNA. Brazil had a high representation in the SPSASCC-17 (50%) and in the South America node (66%), which may unbalance the links between/among participants in the school and further, the interpretation in the SNA. For both networks, we performed a first SNA using connections unweighted by the number of representatives of each group (“unweighted”), and a second one was run using connections weighted by the number of representatives of each group (“weighted”). A combined interpretation of the “weighted” and the “unweighted” analysis allowed to distinguish the effect of Brazil (an overrepresented group) in the social dynamics during the school.

3.2 Terminology and definitions

Two different scenarios were defined in this research (Table 1). A first scenario was called “hypothetical” and represents the optimal situation in which there are no factors affecting the exchange of ideas and a free interaction among the participants during the school. The hypothetical scenario is conceptual and defines the maximum or potential interactions that can be achieved during the school. It is initially limited by the physical characteristics of the studied social group. A second scenario called "real” represented the interactions that effectively occurred during the school. The related data were obtained from a survey and used in social network analyses (details below). Additionally, factors conditioning potential interactions and giving rise to the real scenario were explored. Interactions in the real scenario would ideally lead to products, so after a time the effectiveness of the SPSASCC-17 could be defined by derived productivity (Table 1).

Table 2 Representation of the participants of the SPSASCC-17 in the survey

	South Amca	Africa	Central Amca	Asia	North Amca	Europe	Oceania
Origin	69%	13%	7%	6%	3%	1%	1%
Working/school place	70%	12%	6%	3%	9%	0%	0%

Amca.: America

4 Results

4.1 Characteristics of the SPSASCC-17 surveyed participants

The online interview was responded by 73 out of the 110 (119 but excluding the 9 project leaders) participants of the school (66.4% of participation). A 77% representation was achieved for workplace/studyplace, with 23 of 30 countries present in the survey (Table 2). Half of the respondents from South America were from Brazil (Table 2). The respondents were balanced in terms of gender, being 52% males, and 48% females.

Academic disciplines of the respondents included Natural Sciences (31%), Engineering (24%), Meteorology (12%), Agronomy (10%), Economy diplomacy (7%), and Health Sciences (3%).

The results show four main areas of expertise (research interest): climate change (36%), adaptation and mitigation (19%), greenhouse gas emissions (11%), and land use changes (10%). The rest of the group was evenly distributed among different areas: Hydrology (6%), Social Sciences (4%), Public policies (4%), Ecology and Biodiversity (3%), Agricultural Engineering (2%), Paleoclimate (1%), Natural Science (1%), Geosciences (1%), Energy (1%), and Economics (1%).

Interviewed participants were asked about their experience with the climate change subject. Most of the participants have recently started to study climate change (~45% of the participants have been working/studying climate change for 1 to 3 years, while 18% for less than 1 year). The remaining 37% showed to have more experience in climate change. Of this percentage, 19% had been working/studying this field for 4 to 5 years, 15% for 6 to 10 years and 3% for more than 10 years.

4.2 Perception about the SPSASCC-17

Most of the interviewed participants stated that the school "met their expectations'' (Table 3). The participants declared having had interactions during the poster session, but mostly during social moments (such as coffee break / lunch) (Table 3). Participants declared higher interactions during the second week than in the first one. Most respondents manifested that the duration of SPSASCC-17 was adequate to generate the expected interactions (Table 3).

Table 3 Evaluation of the SPSASCC-17 to achieve the effective interaction objective

# Question	Question	Options	% Responses
9	Did the interactions you had at the SPSASCC-17 meet your expectations?	Yes	69
		No	1,5
		Maybe	3
		Sometimes	25
		To some extent	1,5
12	When did you experience the most effective interactions? (Multiple responses were allowed)	During the first week	24
		During poster presentation[a]	68
		During the second week	56
		During coffee break/lunch	43
		Other (Respondents answers included: On the field trip[b], networking dinner[b], at the hotel)	10
14	Was the duration of the SPSASCC-17 adequate to generate the expected interactions?	Yes	78
		No	8
		Maybe	14

[a]End of the first week; [b]Second week

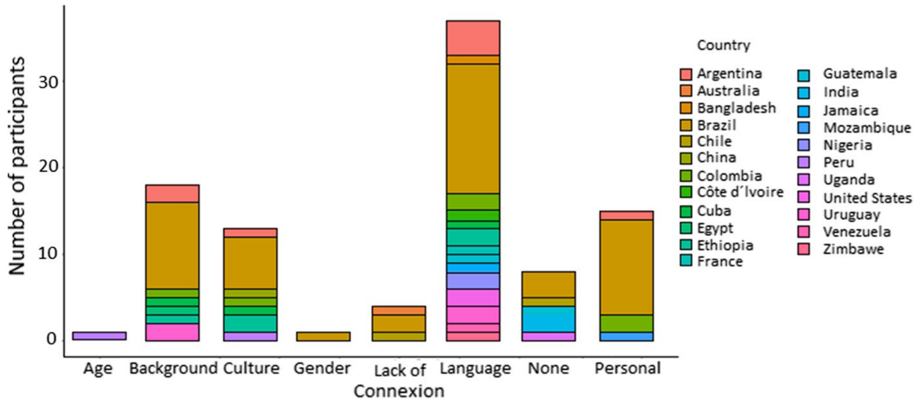

Fig. 1 Frequency of appearance of factors that affect real interactions, depending on the perception of the interview participants, selected from a list of options or manifested based on their personal experiences

5 Factors affecting the interaction

Participants mainly selected factors related to communication (language), knowledge, personality and culture (Fig. 1) as barriers for interaction. Age (1%) and gender (1%) were the least selected factors as barriers for the interaction. Finally, 8% of the respondents did not select any barriers that hindered their ability to interact with their peers during the SPSASCC-17 (Fig. 1), while issues related to "lack of connection" were mentioned as 'other' factors.

Table 4 Expectations and interactions of the SPSASCC-17 survey participants during the school

# Question	Question	Options	% Responses
7	What were your expectations about possible interactions you intended to have with the SPSASCC-17 team? (Multiple answers were allowed)	Participation in publications as co-authors	69
		Contacts for obtaining financial funds	32
		Contacts for advice in your research	69
		Collaboration in projects	87
		Other: (Respondents answers included: Developing inter-university programs, further studies, networking)	8
8	Do you think the interactions you had at the SPSASCC-17 will lead to any future collaborations?	Yes	69
		No	1
		Maybe	30
10	During the course SPSASCC-17, select the region(s) of the people with whom you had effective interactions? (Multiple answers were allowed)	North America	43
		Central America	43
		South America	95
		Africa [a]	60
		Asia [a]	26
		Oceania	11
		Europe	20
11	Select the field (s) of the people with whom you had interaction during SPSASCC-17 (Multiple answers were allowed)	Natural Science	37
		Social Science	27
		Economy	1
		Climate Science	< 1
		Engineering	23
		Health	11
		Other	< 1

[a]The options North, South, East, West and Central were unified into a common group for the analysis

5.1 SPSASCC-17 surveyed participants: interaction analyses

The participants of the survey expected different types of interactions during the SPSASCC-17 (Table 4). Mostly, the respondents believed that the interactions generated during SPSASCC-17 (real scenario) would generate future collaborations, while the minority thought that they would not. Uncertainties were also manifested. Among the participants that were positive about the future interactions, most expected to collaborate in common projects, co-authorship and advice in their research, some looked forward to expanding its network in order to get financial funds and a few suggested other kinds of collaboration (Table 4).

The interactions among the participants were done between participants from different regions. Specifically, participants declared real interactions with people from: 3 different regions (29%), 2 different regions (19%), a single region (19%), 4 different regions (18%) and 5 to 7 regions (15%).

Interactions were also done with colleagues from different disciplines (Table 4). Most of the participants expressed having had "real interactions" with more than one colleague. Participants declared real interactions with: at least with 2 people (43%), with 3 people (29%), with 4 (16%) people, with 1 person (11%), and with 5 colleagues (1%).

Table 5 Interactions *x* working/studying place

Working/school place	Degree	In degree	Out degree	Betweenness
Africa	10	6	6	3.33
Central America	7	5	4	0.33
South America	10	6	6	3.33
North America	7	3	6	0
Asia	6	4	2	0
Europe	6	4	4	0

Unweighted social network analyses: normalized centrality indices for each node composed of working/school place

5.2 Dynamics of the interactions: social network analyses (SNA)

5.2.1 Workplace/studyplace interactions (unweighted SNA)

Global indexes for this network showed a density of 0.77, a clustering of 0.82619, and a modularity forming 3 communities: a) Africa + Europe, b) Asia + North America, and c) Central America + South America.

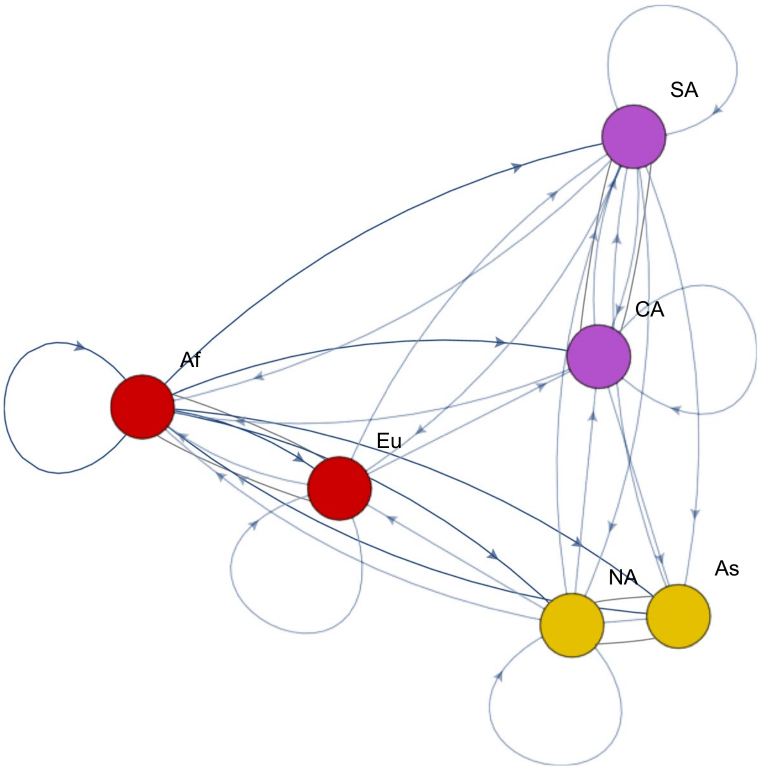

Fig. 2 "Interactions x workplace/studyplace" (network analyses): Node indicates each working/school place category. Lines between nodes represent direct connections. Colors indicate different communities. Red: Africa (Af) + Europe (Eu); Yellow: Asia (As) + North America (NA); Purple: Central America (CA) + South America (SA)

Table 6 Interactions *x* workplace/studyplace

Working/school place	Degree	In degree	Out degree	Betweenness
Africa	10	6	6	3.33
Central America	7	5	4	0.33
South America	10	6	6	3.33
North America	7	3	6	0
Asia	6	4	2	0
Europe	6	4	4	0

Weighted social network analysis: normalized centrality indices for each node composed of working/school place

The local measures centered on the nodes of the elaborated social network are described in Table 5 and Fig. 2.

The average value for the indices was: degree 7.7, IN degree 4.7, OUT degree 4.7, and betweenness 1.2.

Africa and South America shared the highest degree score (10), and both the same IN and OUT degree (6). In the clustering analysis, both regions were placed in different communities. Central America and North America showed the same degree (7) but different IN and OUT degrees and were grouped in different communities. Finally, Asia and Europe shared a degree of 6, the same IN degree but different OUT degree, and were also grouped in different communities.

Participants working/studying in Africa, South America and Central America had the same betweenness index (0.33). The rest of the regions (Asia, Europe and North America) had a betweenness of 0.0.

As an overall result, the communities formed from the interactions of workplaces/studyplaces were balanced in number (two regions each) and with a high mean integration index (mean degree = 7.7). These communities were also balanced in terms of "integration quality," as each community was formed by at least one highly integrated region (e.g., Africa, South America, and Central America) plus one low integrated region (e.g., Europe, Asia and North America).

5.2.2 Workplace/studyplace interactions (weighted SNA)

When Brazil was weighted for the analysis, global indexes for this network showed the same density and a clustering as the unweighted SNA, but a modularity forming 3 communities: a) Africa + Europe, b) Asia + North America + South America, c) Central America.

The local measures centered on the nodes of the elaborated social network are described in Table 6. The average value for the indices was: degree 7.7, IN degree 4.7, OUT degree 4.7, and betweenness 1.2.

5.2.3 Professional interactions (unweighted SNA)

Global indexes for this network showed a density of 0.4, a clustering of 0.437675, and a modularity conforming 3 communities: a) Chemistry + Economy + Math + Politics + Social Science, b) Agronomy + Engineering + Health Science, and c) Meteorology + Natural Sciences.

Table 7 Interactions x profession

Profession	Degree	In degree	Out degree	Betweenness
Natural sciences	14	10	6	16.83
Engineering	12	10	4	0.83
Social sciences	12	9	3	8
Health sciences	10	8	4	0
Agronomy	5	1	4	0
Meteorology	5	0	5	0
Politics and Diplomacy	5	2	5	0.33
Economy	5	1	4	0
Chemistry	3	0	4	0
Math	5	1	4	0

Unweighted social network analyses: normalized centrality indices for each node composed of professions

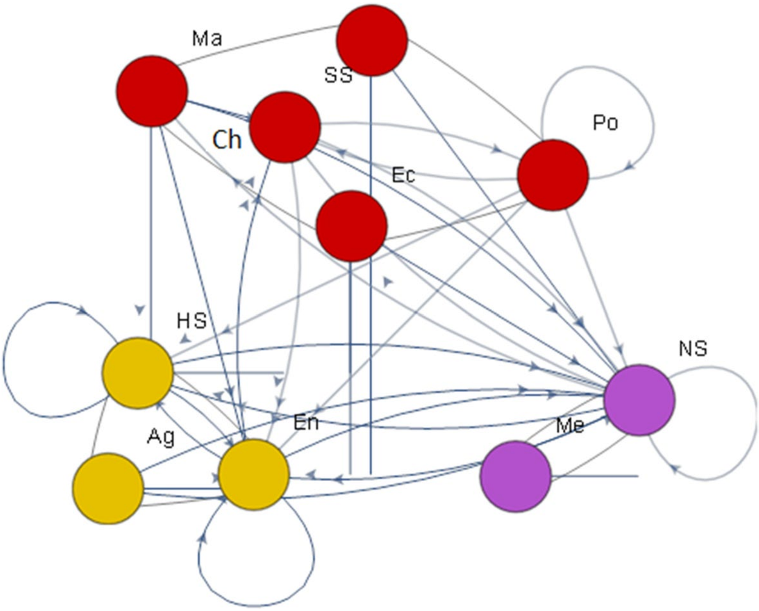

Fig. 3 "Interactions x Professions" (network analyses): Node indicates each profession category. Lines between nodes represent direct connections. Colors indicate different communities. Red: Math (Ma) + Social science (SS) + Chemistry (Ch) + Economy (Ec) + Politics (Po); Yellow: Health science (HS) + Agronomy (AG) + Engineering (En); Purple: Meteorology (Me) + Natural science (NS)

The local measures centered on the nodes of the elaborated social network are described in Table 7 and Fig. 3.

The average value for the indices was: degree 7.6, IN degree 4.2, OUT degree 4.2, and betweenness 2.6. Natural Science showed the highest degree score (14) and a higher IN (10) and OUT (6) degree. Then, Engineering and Social Science shared the same high degree score (12), both had high IN degree scores, and moderate OUT degrees. In the

Table 8 Interactions *x* profession

Profession	Degree	In degree	Out degree	Betweenness
Natural Sciences	14	10	6	17.83
Engineering	12	10	4	1.83
Social Sciences	11	8	3	8
Health Sciences	9	7	2	0
Agronomy	5	1	4	0
Meteorology	5	0	5	0
Politics and Diplomacy	5	2	2	0.33
Economy	5	1	4	0
Chemistry	3	0	3	0
Math	5	1	4	0

Weighted social network analyses: normalized centrality indices for each node composed of professions

clustering analysis, the three mentioned professions were placed in different communities. Health Science showed an intermediate high degree value of 10, with a high IN degree and a regular OUT degree. Then, all Agronomy, Economy, Math, Meteorology and Politics showed the same degree (5) but different IN and OUT degree scores. Finally, the lower degree was shown by Chemistry (3), with low IN and OUT degree scores. These regions were all grouped in different communities.

The betweenness index was higher for Natural Sciences (16.83), followed by Social Science (8), Engineering (0.83), and Politics (0.33). The rest of the professions (Agronomy, Chemistry, Economy, Health Science, Math and Meteorology) had a betweenness of 0.0.

As an overall result, the communities formed from the interactions among professions were numerically unbalanced (five, three and two regions each) but with a relatively high mean integration index (mean degree = 7.6). These communities were balanced in terms of the "integration quality," as each community was formed by at least one highly integrated region (Natural Science, Engineering, Social Science and/or Health Science), plus less active professions (Agriculture, Economy, Math, Meteorology, Politics and/or Chemistry). The mean betweenness index was low, but participants from Natural Sciences and Social Science acted as intermediate.

5.2.4 Professional interactions (weighted SNA)

When extracting Brazil from the analysis, global indexes for this network showed the same density than the unweighted SNA, a clustering of 0.385238, and a modularity conforming 3 communities: a) Chemistry + Economy + Politics + Social Science, b) Agronomy + Engineering + Health Science, and c) Math + Meteorology + Natural Sciences.

The local measures centered on the nodes of the elaborated social network are described in Table 8. The average value for the indices was: degree 7.4, IN degree 4, OUT degree 4, and betweenness 2.8.

6 Discussion

Results of Sect. 3.1 showed that characteristics of the São Paulo School of Advanced Science on Climate Change 2017 (SPSASCC-17) were reflected in the surveyed group. The survey response rate was good (66.4%), representing 77% of the school's professions, satisfying the spirit of gender equity, and the established quota of half of the participants being from Brazil. Furthermore, all the academic disciplines and the diversity of situations in terms of experience in climate change and age ranges were represented in the survey. This comparison enables us to ensure that the results obtained from the survey (sample population) could be extrapolated to the entire school (universe of study).

The participation in interventions for early career scientists, such as networking and training symposia, has been found to have positive impacts on the likelihood of engagement in climate-centric interdisciplinary research (Hein et al., 2018) and may be also important for CC researchers. As socialization is a dynamic and synergistic process that takes place jointly momentarily during interactions (Boromisza-Habashi & Reinig, 2018), the use of central facilities and common areas during the SPSASCC-17 promoted interdisciplinary interactions. As suggested by Eisenberg and Pellmar (2000), respondents included the casual discussion at the coffee machine during coffee break, lunch, fortuitous meeting in the corridor, an interesting seminar, or interactions among students and postdoctoral scientists, especially during poster sessions as suitable environments to develop different types of interactions that trigger collaborations. However, respondents also identified the presence of factors affecting the interaction among the participants, with different levels of relevance. In addition, social networks showed that not all the participants behaved in the same way during the school, and some students were more proactive than others in seeking interaction.

6.1 Factors affecting the interaction

The reason why different types of interactions were observed can be varied and complex at the same time. Initially, academic systems are seen as structured with concentration on specific majors as disciplines, and hence, interdisciplinary integration is seen as innovative from the traditional fields of study (Jones, 2010). It was established that early career researchers perceive conflict between the need for interdisciplinary climate change research and its potential detriment to career advancement (Hein et al., 2018) while others consider the interdisciplinary approach as less efficient, requiring to create time for collaborative teamwork, sometimes hard and exhausting to achieve (Winowiecki et al., 2011). Specifically, despite the many opportunities to interact at the SPSASCC-17, respondents selected factors that hindered the free exchange of knowledge from a list of options and proposed others. This leads to the rejection of the first hypothesis about the existence of a free exchange of ideas among the participants of the SPSASCC-17. From the six tested factors in this study (Appendix 2), participants strongly selected aspects related to communication (language and jargon, intellectual base), and attitude (personal). They also declared new factors as lack of connection, but also the absence of problems to interact. These results are reflecting the existence of initial and previous biases that conditioned interactions during the school (e.g., language, intellectual base or background) but also of emerging ones during the school (e.g., attitudinal barrier).

6.1.1 Language and jargon

More than 50 years ago, English became the official language of international science (Gordin, 2015). Despite this and the fact that one of the requirements to get the scholarship was to have a good English knowledge, the strongest perceived factor affecting the exchange of ideas during the SPSASCC-17 was verified to be the language. This might have been caused by the high representation of non-native English speakers. For instance, Brazilian participants constituted 50% of the attendees, so that Portuguese was the most native-spoken language, followed by Spanish, which accounted for 26% of participants. The remaining 24% of the school spoke different languages, including English. Beyond the statistics, the imbalances and the variety of languages involved, in the social analysis, the perception of a person matters (Tardy, 2004). In the case of language, results of this study are quite conclusive, and the SNA based on the origin (Fig. 2) reflected a collective decision of participants of grouping during the school conditioned by the emergence of the language as a barrier for the exchange (expanded in Sect. 4.2).

Interestingly, this barrier impacted all participants in the survey including both, native English speakers and non-native English speakers, who reported communication difficulties related to language. This is mainly because communication does not work so well in a unidirectional way. To solve this problem, there have been several studies suggesting the inclusion of more than one language in scientific contexts (e.g., Márquez & Porras, 2020; Tardy, 2004). Even though having a common language is important for publishing (Glaze, 2000), a multilingual approach might be better to improve the interactions between new researchers at the start of their careers, letting to include not only the rough science but also cultural points of view (Alves & Pozzebon, 2013; Glaze, 2000). Furthermore, many researchers are forced to learn English for their disciplines when it is not their native language (e.g., Woolston & Osorio, 2019), but not necessarily to socialize outside of their academic comfort zone. That can become an obstacle to social interaction, conditioning their opportunities with respect to other researchers for being part of an international scientific community (Eisenberg & Pellmar, 2000).

There may also be difficulties for the interaction within the academic area, related to the technicalities of the different disciplines. Thus, a recommended strategy to foster interdisciplinary research is using a common topic (Bridle et al., 2013), as climate change was for the SPSASCC-17. Nevertheless, different disciplines use different terminologies leading to ambiguity (Marzano et al., 2006), and the years of expertise that each participant had may have influenced interaction between them. The survey showed that most of the participants (64%) had between 0 and 3 years of experience in this topic (mainly related to Master and initial PhD students) and 34% of them had between 4 and 10 years (mainly related to advanced PhD students and Post-docs). Participants of the SPSASCC-17 could find themselves relatively inexperienced in some areas of climate change, even when they are relative experts in others. This is understandable as technical or professional interactions usually depend on practical relationships with mutual identities, specific codes, and common dialects that are specific to the cultural context of each individual/area of expertise (Márquez & Porras, 2020). Even when the results show that in two weeks the school participants related to each other better, communicating with another discipline required time and work, and many had recognized that this barrier must be overcome before successful collaboration can occur (Andrews, 1990; Kane, 1975; Sigma Xi, 1988).

6.1.2 Intellectual base

Respondents selected “background” as the second strongest proposed barrier to reduce the effective communication with other participants during the SPSASCC 2017 (Appendix 2). The “background” factor could be associated with the level of studies and/or specialty (expertise) or to the general knowledge of the person. The SPSASCC-17 sought to bring together early career researchers from different disciplines with common interest in the field of climate change as by definition, interdisciplinary efforts bring together researchers who have different expertise (Eisenberg & Pellmar, 2000); however, the exchange of knowledge among disciplines can be intense (Winowiecki et al., 2011). The SNA results suggest that participants actively sought and promoted interdisciplinary interactions, with some background professions with greater affinity to each other (Fig. 3): (a) Chemistry + Economy + Math + Politics + Social Science, b) Agronomy + Engineering + Health Science, and c) Meteorology + Natural Sciences). Nevertheless, they were all directly or indirectly connected (expanded in Sect. 4.2), so the “background” related to the expertise factor would have some weight in the interactions, but not determinant.

Differently, as earlier stated, even when most of the participants were in the initial stage of climate-related research, they had different levels of knowledge influencing the intention of exchange and interactions. Researchers’ mindsets and beliefs are associated with their strategic research approaches to shape research production (Santos & Horta, 2020). Previous conceptions of research influence the motivations, decisions, and aptitudes related to engagement in research choices and interests (Niiniluoto, 2020). Thus, a possible strategy connected to the "background" factor may be to join with more experienced researchers to fill research agendas, namely scientific ambition, collaboration, discovery, academia-driven approach, and society-driven approach (Santos & Horta, 2020). Either way, Bridle et al. (2013) found that significant diversity in background, culture and discipline in similar encounters might require a longer time for the group to develop connections.

6.1.3 Attitudinal barrier

The personal factor was the third strongest barrier perceived by the participants of the school to achieve interactions. Eisenberg and Pellmar (2000) discuss that interdisciplinary science can be hindered by the perception of the need or not of interdisciplinary science, or even on personal concerns about seeing interdisciplinary research as not “pure,” “less challenging,” “high risk” or “with lack of professional identity.” On the other hand, interactions could be limited simply because of personal feelings about each other (also related to “lack of connection” in the survey; Fig. 1). Relationships among team members have been reported to affect productivity (Barrick et al., 1998; Winowiecki et al., 2011), so personal issues such as lack of empathy or connection could be a serious problem in interdisciplinary teams as fundamental for a leader to lead. According to Winowiecki et al. (2011), this situation could sometimes be unraveled through active interaction exercises, such as reflection work in randomly generated small groups. The language factor may also be related to this item since within “personal factors” the influence of affective states on communication in a foreign language can be evoked (Volpin et al., 2017).

An interesting and encouraging finding from this study is the observation that both age and gender are not factors currently having a negative weight, at least within the SPSASCC-17 group, when interacting with each other. Every participant tried to interact independently of their age or gender to maximize the potentials and opportunities during the gathering. This indicates that previously significant old barriers are currently being overcome as this result is contrary to previous studies (Bozeman & Gaughan, 2011; Jadidi et al., 2018; Lee & Bozeman, 2005).

6.2 Social network analyses

The use of the social network analysis (SNA) allowed us to describe the global structure of the two studied networks in the SPSASCC-17 (Fig. 2 and 3). In both cases, the appearance of three subgroups or communities was detected, so the absence of free exchange among the participants can be determined, rejecting hypothesis 2 of this work. It was assumed that the nodes of each community share attributes, common characteristics or fundamental connections, which in turn differentiate them from another community.

The density index showed that the participants from the school were looking for interactions (real scenario), although the maximum (hypothetical scenario) was not achieved. In the same direction, both SNA manifested 3 groupings or clustering indexes far from 1, which denotes the absence of totally free interactions among the participants of the SPSASCC-17, but it reflects the intention to cooperate (Kuperman & Risau-Gusman, 2012). This pattern can be associated with the activation of barriers beyond the physical characteristics of the school, which were identified through the semi-structured query and discussed above. Initially, the factors manifested as conditioning the interactions (mainly language and/or personal) could be followed. Once segregated by the barriers, the students were able to generate heterogeneous communities, seeking interdisciplinary. These and other reasons were possible to be observed through the global analysis of the networks.

Through modularity, 3 groups with the stronger interactions for the SNA were found. Origin network showed the stronger aggrupation for participants of: A) Africa with Europe, B) South America with Central America, and C) North America with Asia. The clearest explanation of these groupings is found in the strongest barrier expressed by the participants of the school, the language. Mostly, the three groups either had similar native languages or their second language connected them. It is possible that other factors stimulate the grouping, for example, common lines of research or grants between nations. Europe and Africa are closely related through numerous conventions, bilateral research and extension agreements (e.g., The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) Program, The System-wide Livestock Programme (SLP) of the CGIAR, The African Urban Resource Typology, etc.). The same goes for South America and Central America (e.g., CEPAL, Mercosur, Comisión Centroamericana de Ambiente y Desarrollo (CCAD), Comunidad Andina (CAN), Instituto de Estudios Políticos para América Latina y África (IEPALA), etc.). In the C group, as very few participants of the school were from those regions, their professions and jobs were possible to be identified, which mostly join them in the common area of modeling and remote sensing.

Connections were not restricted to groupings, but for professions, three communities were also found. Groups consisted of A) Meteorology + Natural science, B) Math + Social science + Chemistry + Economy + Politics, and C) Health science + Agronomy + Engineering. Regardless of the particular interests within each group, the emergence of communities from the professional network reflects the search for multi-disciplinary (several disciplines each contributing independently to the problem) and / or interdisciplinary interactions (several disciplines in a specific aspect but crossing the traditional boundaries between them).

The degree index of these networks can be related to the number of connections that each profession or workplace/studyplace had during the school, in which case it quantifies the connectivity. Based on the degree index score, the connections made by profession decreased in a sequence: Natural Science (14) > Engineering (12) = Social Science (12) > Health Science (10) > Agronomy (5) = Economy (5) = Math (5) = Meteorology (5) = Politics > Chemistry (3). Regarding the origin, the capacity to generate connections decreased in a sequence: Africa (10) = South America (10) > Central America (7) = North America (7) > Asia (6) = Europe (6). In the clustering analysis, the professions and the workplace/studyplace with high, medium and low degrees were distributed in a balanced way in the three different communities. This means that the communities were homogeneous in terms of their overall potential to interact internally and with the others. The measures of IN and OUT degrees showed a similar overall trend. The former nodes (Natural Science and Africa) can be seen as more popular and sociable than the last ones (Chemistry and Europe). However, the IN degrees were higher (double to triple) that OUT degrees in Natural Science, Engineering, Social Sciences, and Health Science, indicating more inbreeding interactions (loops) in the former disciplines than in the rest of the analyzed, which showed a lower general degree but a higher (double to quintuple) OUT degree. The latter did not happen for workplace/studyplace, with very similar IN–OUT degrees. These results showed that regions or professions with a good ability to generate interactions (high degree) were not only linked with themselves and others of similar qualities, but showed higher affinity with less active participants (low degree); this is symptom of empathy and a natural organization of the school looking for an intercultural and interdisciplinary highly efficient work, without letting apart isolated participants. Different studies have shown that favoring care and cooperation (e.g., Garaigordobil & Berrueco, 2011; Garaigordobil Landazabal, 2004, 2005), as well as empathic processes (e.g., Czar et al., 2019; Kok & Singer, 2017) can positively modulate social ties and increase social connectivity.

Analyzing within the groups, local measures centered on the nodes can also show social integration, through indicators such as “degree” (IN and OUT) and “betweenness.” The betweenness index shows that participants from Natural Sciences had the highest potential to encourage collaborations through them, followed by Social Science, Engineering, and Politics. However, the rest of the professions (Agronomy, Chemistry, Economy, Health Science, Math and Meteorology) had a betweenness of 0.0, so they did not act as intermediators. The betweenness index showed that participants working/studying in Africa, South America and Central America had the same (0.33) and highest potential to encourage collaborations through them. The rest of the regions (Asia, Europe and North America) had a betweenness of 0.0, implying they did not act as intermediators. Higher scores of connections through real interactions were achieved in work/school-locations or professions least represented in the survey. This implies a higher and more active participation of people belonging to underrepresented regions or professions in the school in the specific objective of experiencing “real interactions.” Some highly related participants (possible leaders) acted as bridges to lower ones, promoting integration and interdisciplinary (e.g., Natural Science or Engineering). However, the betweenness index also evidenced that possible leaders were not always the links to others (e.g., Health Science). This represents a leader that would not promote interaction with others outside of his/her action network. This is a case of a positive personal quality that becomes useless for the community if not shared. These results express natural positive and negative human traits, which could occur in social connections of any field.

A well-connected network will have a high influence on the early career researchers, with a long future in climate change research ahead. The interactions among the participants were done between participants from different regions (mostly with 3 different regions) and from different disciplines (mostly 2 or 3 people) which together with the balanced network from the sample population, denote a proactive group that took advantage of the given opportunity. Interactions between different stages-ages also stimulate the exchange between more experienced researchers and juniors, a social process that may also promote effective interactions. Network analysis allowed us to see an interesting degree of interaction, especially between individuals associated with different scientific disciplines focused on CC. The analysis of communities indicates that the connections reflected interactions between people coming from the hard and the soft sciences in a very interesting way. This reflects the interdisciplinary character of the interactions, to which we have already alluded, and the motivation of the participants to look beyond the limits of their own discipline.

Since the preponderance of Brazil in the school, it was expected that the SNAs weighted by Brazil would be different from those unweighted by Brazil. However, the global indicators remained similar in both cases, so the greater proportion of Brazil in the school did not substantially condition the global structure of the networks nor the social dynamics among the nodes during the school. This can show that participation quota decisions based on benefits for the host country could continue being an option, since it does not seem to condition this aspect much, at least up to 50%. However, it is also indicating that, despite the high representativeness in the school, the Brazilian participants did not fully exploit their potential to achieve more interactions during the school, as other participants did. This was attributed to a "hosting effect." As an essential element for defining early career interdisciplinary research, Drake (2003) proposes that changing location and stepping out of ''comfort zones'' have been linked with enhanced creativity. Brazil obtained 50% of the SPSASCC-17 quota, with many of the participants attending the school, working, or living in Sao Paulo at the same time, and staying in their comfort zone. In addition, although modularity shows stronger groupings, this does not imply the absence of a multiplicity of interactions among the nets. Grouping is an inherent response of people in social environments, as being part of a net brings health and wellbeing (Cacioppo et al., 2015; Kok & Fredrickson, 2010; Kornienko et al., 2015; Taylor, 2011), which can be emphasized by being away from home. During SPSASCC-17, foreign people from different regions spend large amounts of hours together, during different types of activities or situations, and "real interaction" was naturally built (while locals—with exceptions— remain in their own classes, offices, or houses or with their own partners, friends or family or are even part of the school's local organizing committee). The largest number also deepens the effect of the detected barriers (language and background). Being the host had advantages in several ways, but did not improve the interaction rates. The school was a good framework to initiate collaborations, and although Brazil was overrepresented, the "hosting effect" matched it with the rest of the school. This aspect was also verified through the participatory observation of the leaders of this project. International events can generate benefits and costs for the host destination (Jago et al., 2010). Being aware of this "hosting effect" could promote active behaviors of methods to increase benefits for hosting, including the interactions among all actors (enhancing the density factor), which is one of the main objectives of such types of meetings.

It is interesting to mention that the survey shows that most of the interviewed participants "met their expectations" of the achieved interactions during the SPSASCC-17. Most of the interactions were declared to be done during academic moments, as the poster session, but social moments (coffee break/lunch) also achieved high percentages of interactions. Particularly, participants took advantage of meetings at the hotel where many of the foreign participants stayed to effectively interact. Social interactions may be more important to connect people than the academic structure in training courses. Most respondents manifested that the duration (two weeks) of SPSASCC-17 was adequate to generate the expected interactions, and however, higher interactions were declared during the second week with respect to the first one. The first week would be a period of mutual evaluation, to establish compatibility of profiles and interests. Higher levels of interactions were reached during the second week, which means that the establishment of effective interactions needs time.

As research limitations, it can be mentioned the anonymous nature of the survey established to give confidence to the participants, lead to a lack of directionality in the worked parameters and prevent from carrying out further analysis. Further, the symmetry in a directional network is a measure of reciprocity, while an asymmetrical network indicates the absence of equal perceptions. The structure of the survey does not allow to know the origin of the connections, so the asymmetry found may be due to discrepancies in perceptions or to an unequal directionality of manifested interactions between nodes. Similarly, the inquiry of the "background" factor could be improved to differentiate nuances associated with its possible meanings/interpretations. Finally, the study relies on self-reported perceptions, with an inherent risk of response bias and a limitation of the findings.

Summarizing, as participant observers, the research group found in the SPSASCC-17 barriers and drivers for the exchange among early career researchers. Some barriers constitute initial and previous biases that conditioned interactions during the school (e.g., language or background) and others emerged during the event (e.g., lack of connection). Particular dynamics were detected among the studied group, enhancing and/or conditioning possible interactions. Although the school was conducted in English, language was the strongest factor affecting interactions among participants, followed by background, culture and personal aspects. Gender and age were not considered as a limiting factor to achieving effective interaction. Performed SNA was affected by the factors mentioned above and allowed to detect the grouping of participants during the school. Initially, the factor manifested as mainly conditioning interactions (language or personal feelings) seems to be followed. Once segregated by the barriers, heterogeneous communities seeking interdisciplinary approaches were generated. The study identified popular nodes dedicated to integrating others not so sociable. Leaders with the potential to bring less active participants to their work nucleus but not promoting the interaction with outsiders were detected. Brazil was the country with the most representation in the school (50% of quota), yet did not show higher interactions than the school average, through the so-called “hosting effect.” Two weeks were identified as enough time to make first professional connections in a group such as the one studied here; however, more time and directed activities would be necessary to overcome barriers for the interaction. Indications from this study are encouraging, as shows that new generations of researchers understand the need of interdisciplinary research and collaborations among scientists from different backgrounds.

7 Conclusion

This study identified factors and social dynamics influencing the effectiveness of group interactions among early career researchers working toward environmental sustainability in CC. Using qualitative and quantitative data, perceived indicators related to barriers (e.g., language and background) and drivers (e.g., gender and age) were linked to the structure of the two active social networks analyzed: workplace/studyplace, and professions. Network analysis revealed connections between researchers coming from the Natural and Social sciences, showing interdisciplinary behavior and motivation to go beyond the limits of their own discipline. However, different factors and behaviors challenging the goal of collaborative networks were found. Based on the detected barriers, organizers of future interdisciplinary events are encouraged to actively overcome these limitations, by: 1) assembling working groups from different disciplines, origins/languages, and academic background of participants; 2) establishing concrete practical exercises; 3) identifying early in the process the potential leaders who could strategically boost their roles during the event; and 4) encouraging locals to engage in networking activities ("hosting effect"). To holistically address CC, the construction of the interdisciplinary research approach is promoted by taking into account the culture, beliefs, and conceptualization aspects at a group level without overlooking individual preferences.

Appendix 1

See Table 9.

Appendix 2 Survey

Dear SPSASCC colleagues: we will appreciate if you can complete the following quiz for a small research on the communication between the participants during the advanced school. Thank you very much.

*Required

(1) Which country are you from? *

____

(2) Gender: *

Mark only one oval.

- Male
- Female
- Prefer not to say
- Other:

(3) What is your profession (e.g.: environmental engineer)? *

____

(4) In relation to the theme of the SPSASCC, what is your area of expertise? *

Table 9 Number of participants of the SPSASCC per country of residence (in alphabetic order) and per current occupation/degree

#	Country of Residence	Master student	PhD candidate	Postdoctoral researcher	Other	Total
1	Argentina	0	3	4	0	7
2	Bangladesh	0	1	0	0	1
3	Bolivia	0	1	0	0	1
4	Brazil	15	39	9	4	67
5	Canada	1	1	0	0	2
6	Chile	0	2	1	0	3
7	Colombia	1	1	0	0	2
8	Costa Rica	0	0	0	1	1
9	Côte d´Ivoire	0	1	0	0	1
10	Cuba	0	2	0	0	2
11	Egypt	0	1	1	0	2
12	Ethiopia	0	1	0	0	1
13	Guatemala	0	2	0	0	2
14	India	0	1	1	0	2
15	Jamaica	0	1	0	0	1
16	Kenya	0	1	0	0	1
17	Mexico	0	2	0	0	2
18	Mozambique	0	0	0	1	1
19	Nepal	0	1	0	0	1
20	Nigeria	0	1	1	0	2
21	Peru	1	0	0	0	1
22	Portugal	0	1	0	0	1
23	Russia	0	1	0	0	1
24	South Africa	0	2	0	0	2
25	Togo	0	1	0	0	1
26	Turkey	0	0	1	0	1
27	Uganda	0	1	0	0	1
28	Uruguay	0	2	0	0	2
29	USA	0	3	0	0	3
30	Venezuela	0	4	0	0	4

Data provided by the SPSASCC organizing committee (INCLINE, 2017)

____

(5) Which country are you studying/working in? *

____

(6) How long have you been working on climate change or climate variability? *

Mark only one oval.

- Less than 1 year
- 1–3 years
- 4–5 years
- 6–10 years
- Over 10 years

(7) What were your expectations about possible interactions you intended to have with the SPSASCC 2017 participants? * *Tick all that apply.*

- Participation in publications as co-authors
- Contacts for advice in your research
- Contacts for obtaining financial funds
- Collaboration on projects
- Other:

(8) Do you think the interactions you had at the SPSASCC 2017 will lead to any future **Collaborations? *** *Tick all that apply.*

- Yes
- No
- Maybe
- Other:

(9) Did the interactions you had at the SPSASCC 2017 meet your expectations? *

Mark only one oval.

- Yes
- No
- Maybe
- Sometimes
- Other:

(10) During the course SPSASCC 2017, select the region(s) of the people with whom you had effective interactions? (You can select multiple options) * *Tick all that apply.*

- North America

- Africa
- Asia
- Central America
- South America
- Oceania
- Europe
- Other: ________

(11) Select the field (s) of the people with whom you had interaction during SPSASCC (You can select multiple options): * *Tick all that apply.*

Natural Sciences

- Engineering
- Social Sciences
- Health Sciences
- Other: __________

(12) When did you experience the most effective interactions? * *Tick all that apply.*

- During the first week
- During the second week
- During the poster presentation
- During coffee break/lunch
- Other:

(13) Select the barriers that reduced your effective communication with other participants during the SPSASCC 2017 (You can select multiple options) * *Tick all that apply.*

- Language
- Culture
- Gender
- Personal
- Age
- Background
- Other:____________

(14) Was the duration of the SPSASCC 2017 adequate to generate the expected interactions? * *Tick all that apply.*

Mark only one oval.

- Yes
- No
- Maybe

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Code availability Not applicable.

Declarations

Conflicts of interest The authors declare that they have no conflict of interest.

Consent for publication The students of the Sao Paulo School of Advanced Science on Climate Change 2017, who participated in the surveys, accepted the statement of publishing the answers they provided.

Ethics approval The participants in the conducted surveys agreed on sharing their answer in an anonymous way.

Consent to participate The participation of the students of the Sao Paulo School of Advanced Science on Climate Change 2017 in the surveys was totally optional.

References

Allen, M., Antwi-Agyei, P., Aragon-Durand, F., Babiker, M., Bertoldi, P., Bind, M., et al. (2019). Technical Summary: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

Alves, M. A., & Pozzebon, M. (2013). How to resist linguistic domination and promote knowledge diversity? *Revista De Administração De Empresas, 53*, 629–633. https://doi.org/10.1590/S0034-759020130610

Andrews, A. B. (1990). Interdisciplinary and interorganizational collaboration. *Encyclopedia of social work*, 1479–1489.

Barrick, M. R., Stewart, G. L., Neubert, M. J., & Mount, M. K. (1998). Relating member ability and personality to work-team processes and team effectiveness. *Journal of Applied Psychology, 83*(3), 377.

Borgatti, S. P., Mehra, A., Brass, D. J., & Labianca, G. (2009). Network analysis in the social sciences. *Science, 323*(5916), 892–895.

Boromisza-Habashi, D., & Reinig, L. (2018). Speech genres and cultural value in the Anglo-American public speaking course as a site of language socialization. *Journal of International and Intercultural Communication, 11*(2), 117–135.

Bozeman, B., & Gaughan, M. (2011). How do men and women differ in research collaborations? An analysis of the collaborative motives and strategies of academic researchers. *Research Policy, 40*(10), 1393–1402.

Bridle, H., Vrieling, A., Cardillo, M., Araya, Y., & Hinojosa, L. (2013). Preparing for an interdisciplinary future: a perspective from early-career researchers. *Futures, 53*, 22–32.

Butlin, J. (1989). Our common future. By World commission on environment and development. London, Oxford University Press, 1987, pp. 3835£.95.

Cacioppo, J. T., Cacioppo, S., Capitanio, J. P., & Cole, S. W. (2015). The neuroendocrinology of social isolation. *Annual Review of Psychology, 66*, 733–767.

Carmin, J., Tierney, K., Chu, E., Hunter, L. M., Roberts, J. T., & Shi, L. (2015). *Adaptation to climate change* (pp. 164–198). Climate change and society.

Carrington, P. J., Scott, J., & Wasserman, S. (2005). *Models and methods in social network analysis (Vol 28)*. Cambridge University Press.

Csardi, G., & Nepusz, T. (2006). The igraph software package for complex network research. *InterJournal, Complex Systems, 1695*(5), 1–9.

Czar, A., Kapelmayer, M., Kelmanowicz, V., Esteves, S., & Lozada, M. (2019). Intervenciones basadas en gratitud y optimismo reducen las interacciones sociales negativas en niños.

Drake, G. (2003). This place gives me space: place and creativity in the creative industries. *Geoforum, 34*(4), 511–524.

Eisenberg, L., & Pellmar, T. C. (2000). Bridging disciplines in the brain, behavioral, and clinical sciences.

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. (2016). Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. *Geoscientific Model Development, 9*(5), 1937–1958.

Fankhauser, S. (2017). Adaptation to climate change. *Annual Review of Resource Economics, 9*, 209–230.

Freeman, L. C. (1978). Centrality in social networks conceptual clarification. *Social Networks, 1*(3), 215–239.

Garaigordobil Landazabal, M. T. (2004). Juegos cooperativos y creativos para grupos de niños de 10 a 12 años.

Garaigordobil Landazabal, M. T. (2005). Programa Juego, 6 a 8 años: juegos cooperativos y creativos para grupos de niños de 6 a 8 años.

Garaigordobil, M., & Berrueco, L. (2011). Effects of a play program on creative thinking of preschool children. *The Spanish Journal of Psychology, 14*(2), 608–618.

Gaziulusoy, A. I., Ryan, C., McGrail, S., Chandler, P., & Twomey, P. (2016). Identifying and addressing challenges faced by transdisciplinary research teams in climate change research. *Journal of Cleaner Production, 123*, 55–64.

Gest, J. (2016). *The new minority: white working class politics in an age of immigration and inequality*. Oxford University Press.

Glaze, W. H. (2000). The universal language. *Environmental Science & Technology, 34*(17), 369A-369A.

Gordin, M. (2015). *Scientific Babel: the language of science from the fall of Latin to the rise of English*. Profile Books.

Hanneman, R. A., & Riddle, M. (2005). Introduction to social network methods.

Hein, C. J., Ten Hoeve, J. E., Gopalakrishnan, S., Livneh, B., Adams, H. D., Marino, E. K., & Susan Weiler, C. (2018). Overcoming early-career barriers to interdisciplinary climate change research. *Wiley Interdisciplinary Reviews: Climate Change, 9*(5), e530.

Jadidi, M., Karimi, F., Lietz, H., & Wagner, C. (2018). Gender disparities in science? Dropout, productivity, collaborations and success of male and female computer scientists. *Advances in Complex Systems, 21*(03n04), 1750011.

Jago, L., Dwyer, L., Lipman, G., van Lill, D., & Vorster, S. (2010). Optimising the potential of mega-events: an overview. *International Journal of Event and Festival Management., 1*, 220–237.

Jones, C. (2010). Interdisciplinary approach-advantages, disadvantages, and the future benefits of interdisciplinary studies. *Essai, 7*(1), 26.

Kane, R. A. (1975). The interprofessional team as a small group. *Social Work in Health Care, 1*(1), 19–32.

Kok, B. E., & Fredrickson, B. L. (2010). Upward spirals of the heart: autonomic flexibility, as indexed by vagal tone, reciprocally and prospectively predicts positive emotions and social connectedness. *Biological Psychology, 85*(3), 432–436.

Kok, B. E., & Singer, T. (2017). Phenomenological fingerprints of four meditations: differential state changes in affect, mind-wandering, meta-cognition, and interoception before and after daily practice across 9 months of training. *Mindfulness, 8*(1), 218–231.

Komiyama, H., & Takeuchi, K. (2006). Sustainability science: building a new discipline. *Sustainability Science, 1*, 1–6.

Kornienko, O., Santos, C. E., & Updegraff, K. A. (2015). Friendship networks and ethnic-racial identity development: contributions of social network analysis. In C. E. Santos & A. J. Umaña-Taylor (Eds.), *Studying ethnic identity: methodological and conceptual approaches across disciplines.* American Psychological Association.

Kueffer, C., Underwood, E., Hadorn, G. H., Holderegger, R., Lehning, M., Pohl, C., et al. (2012). Enabling effective problem-oriented research for sustainable development. *Ecology and Society*. https://doi.org/10.5751/ES-05045-170408

Kuperman, M., & Risau-Gusman, S. (2012). Relationship between clustering coefficient and the success of cooperation in networks. *Physical Review E, 86*(1), 016104.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., et al. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science, 7*(1), 25–43.

Lee, S., & Bozeman, B. (2005). The impact of research collaboration on scientific productivity. *Social Studies of Science, 35*(5), 673–702.

Lyall, C., Bruce, A., Marsden, W., & Meagher, L. (2013). The role of funding agencies in creating interdisciplinary knowledge. *Science and Public Policy, 40*(1), 62–71.

Márquez, M. C., & Porras, A. M. (2020). Science communication in multiple languages is critical to its effectiveness. *Frontiers in Communication, 5*, 31.

Marzano, M., Carss, D. N., & Bell, S. (2006). Working to make interdisciplinarity work: investing in communication and interpersonal relationships. *Journal of Agricultural Economics, 57*(2), 185–197.

Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P. R., et al. (2018). Global warming of 1.5 C. *An IPCC Special Report on the Impacts of Global Warming of, 1*, 1–9.

National Research Council. (2014). *Convergence: Facilitating transdisciplinary integration of life sciences, physical sciences, engineering, and beyond*. National Academies Press.

Newman, M. E. (2012). Communities, modules and large-scale structure in networks. *Nature Physics, 8*(1), 25–31.

Niiniluoto, I. (2020). Social aspects of scientific knowledge. *Synthese, 197*(1), 447–468.

Rosen, M. A. (2012). Engineering sustainability: a technical approach to sustainability. *Sustainability, 4*(9), 2270–2292.

Santos, J. M., & Horta, H. (2020). The association between researchers' conceptions of research and their strategic research agendas. *Journal of Data and Information Science, 5*(4), 56–74.

Scott, J. (2011). Social network analysis: developments, advances, and prospects. *Social Network Analysis and Mining, 1*(1), 21–26.

Tardy, C. (2004). The role of English in scientific communication: lingua franca or tyrannosaurus rex? *Journal of English for Academic Purposes, 3*(3), 247–269.

Taylor, P. W. (2011). *Respect for nature*. Princeton University Press.

Telteu, C.-E., Müller Schmied, H., Thiery, W., Leng, G., Burek, P., Liu, X., et al. (2021). Understanding each other's models: a standard representation of global water models to support improvement, intercomparison, and communication. *Geoscientific Model Development Discussions, 14*, 3843–3878.

Volpin, L., Marian, K. S., Gfeller, F., Gonzalez, S., & Bangerter, A. (2017). Young researchers conference of the centre for research on social interactions. *Studies in Communication Sciences, 17*(2), 263–270.

Winowiecki, L., Smukler, S., Shirley, K., Remans, R., Peltier, G., Lothes, E., et al. (2011). Tools for enhancing interdisciplinary communication. *Sustainability Science practice and policy, 7*(1), 74–80.

Woolston, C., & Osorio, J. (2019). When English is not your mother tongue. *Nature, 570*, 265–267.

Sigma Xi, the S. R. S. (1988). *Removing the boundaries: Perspectives on cross-disciplinary research: Final report on an inquiry into cross-disciplinary science*. Sigma Xi, The Scientific Research Society.

Yazan, B. (2015). Three approaches to case study methods in education: Yin, Merriam, and Stake. *The Qualitative Report, 20*(2), 134–152.
Yin, R. K. (2009). *Case study research: design and methods Vol 5*. Sage.

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