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Research collaboration networks in Latin American geography education

Redes de colaboración en investigación en la educación geografía latinoamericana

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Abstract

The current development of science is characterized by a global trend of scientific collaboration (SC). However, this growth has been mostly linked to intra-national cooperation. Several factors including geographic, institutional, and social proximities have been identified as key for promoting or hinder collaboration among scholars. Based on these premises, the present study analyses the co-authorship and affiliation relationships among geography education researchers in Latin America, exploring through a general trend and social network analysis, the characteristics of SC in geography education. For this purpose, 1774 articles (922 co-authored) published within the region were included as part of the data used for understanding the structure of SC. The results showed an increasing and dominant pattern of co-authoring in the region, but mostly developed at the local and national scale, with scarce intra-regional research. Moreover, the network analysis showed that there are some institutions with a dominant role in the production of research, and a loose network structure of research that could foster diverse perspectives on the field. These findings offer opportunities for thinking about how to enhance future SC processes in the region to strengthen the development of geography education research based on a regional collaborative approach.

Key words: *scientific collaboration, research network, geography education, Latin America.*

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Resumen

El desarrollo actual de la ciencia se caracteriza por una tendencia global de colaboración científica (SC). Sin embargo, este crecimiento está mayoritariamente relacionado con cooperación intra-nacional. Factores como la proximidad geográfica, institucional y social han sido identificados como claves para promover o dificultar la colaboración entre académicos. Basado en estas premisas, el estudio analiza las relaciones de coautoría y afiliación entre investigadores de educación geográfica en América Latina, explorando a través de análisis de tendencia general y redes sociales, las características de SC en educación geográfica. Para este propósito, 1774 artículos (922 en coautoría) publicados dentro de la región fueron incluidos como parte de los datos para entender la estructura de SC. Los resultados muestran un patrón de aumento y dominancia de la coautoría en la región, mayoritariamente desarrollada en escalas locales y nacionales, con pocos estudios intra-regionales. El análisis de redes mostró que hay instituciones con un rol dominante en la producción de investigación, y una estructura poco definida que promueve diferentes perspectivas en el campo. Estos resultados ofrecen oportunidades para pensar sobre cómo mejorar los procesos de SC en la región, fortaleciendo el desarrollo de investigación en educación geográfica basada en un enfoque colaborativo regional.

Palabras clave: *colaboración científica, red de investigación, educación geográfica, Latinoamérica.*

Introduction

Scientific collaboration (SC) can be understood as a process of knowledge creation and sharing between two or more individuals, where experiences and resources are placed for achieving scientific goals, transmitting, and diffusing new knowledge (Ponds, van Oort and Frenken, 2007; Yao *et al.*, 2021). Researchers often collaborate to engage in global scientific issues that are complex and require interdisciplinary perspectives like climate changes pollution, energy, health, among others (Lee and Bozeman, 2005; Royal Society, 2011; Adams and Loach, 2015; Wagner, Whetsell and Mukherjee, 2019). By doing SC, scholars are more likely to share resources, equipment, and facilities, as well as to integrate knowledge, skills, and abilities to solve these challenges (Katz and Martin, 1997; Franceschet and Constantini, 2010; Yao *et al.*, 2021).

The development of science has become a global process of scientific collaboration (Wagner and Leydesdorff, 2005; Adams, 2013), where researchers perceive the value of working with colleagues (Matthews *et al.*, 2020) and thus, create interconnected networks of science, some of them eased by the availability of technologies (Altbach, 2004; Leydesdorff and Wagner, 2008; Gui, Liu and Du, 2019). In fact, co-authoring articles have been associated to more citations (Glänzel, 2001; Persson, 2010; Gazni, Sugimoto and Didegah,

2012; Sugimoto *et al.*, 2017; Fortunato *et al.*, 2018), increased productivity, innovation, high-quality, and high-impact research (Abramo, D'Angelo and Solazzi, 2011; Larivière *et al.*, 2014; Csomós, Vida and Lengyel, 2020).

The production SC articles has increased during the 21st century worldwide (Royal Society, 2011; Waltman, Tijssen and Eck, 2011; Gazni, Sugimoto and Didegah, 2012; Larivière *et al.*, 2014; Larivière *et al.*, 2016). Although several authors identified a rise of international SC (Wagner, Whetsell and Leydesdorff, 2017; Ribeiro *et al.*, 2018; Yao *et al.*, 2021), most of the growth has been linked to an intra-national or local scale (Hennemann, Rybski and Liefner, 2012; Abbasi and Jaafari, 2013; Maisonobe *et al.*, 2016).

Moreover, the global trends of SC tend to be greater among the developed regions of North America, Europe, South-east Asia and the Pacific (Ortega and Aguillo, 2012; Grosetti *et al.*, 2014; Gui, Liu and Du, 2019). Countries with greater economic, scientific welfare, and social development tend to produce more SC (Zanotto, Haeffner and Guimarães, 2016; Chinchilla-Rodríguez, Sugimoto and Larivière, 2019; Hou, Pan and Zhu, 2021). Evidence of SC in geography fields support the prevalence of these scientific networks, with United States at the top of international research collaboration (Wang and Liu, 2014; Liu *et al.*, 2016; Chao and Tian, 2018).

There is evidence of an increase of SC research in developing regions and countries during the 21st century (Gossart and Ozman, 2009; Royal Society, 2011; Buchelli *et al.*, 2012). Studies suggest that the relative size of emerging countries and national funding schemes promotes networks of local SC (Glänzel and Schubert, 2005; Chinchilla *et al.*, 2010; Bergé, 2017). The growing number of Latin American international SC research (Vanz and Stumpf, 2012) is often produced either with scientists from extra-regional countries or within national borders, as intra-regional SC has been found to be limited and, in some cases, restricted for countries with a small scientific development (Vanz and Stumpf, 2012; Stumpf *et al.*, 2013; Munoz, Queupil and Fraser, 2016). Additionally, Latin American SC exhibits spatial heterogeneity patterns, as geographical proximity becomes critical, and most research occurs in specific cities within the countries, therefore remaining mostly local (Munoz, Queupil and Fraser, 2016; Sidone, Haddad and Mena-Chalco, 2017; Da Silva *et al.*, 2018).

Although there are some regional studies in geography about semi-peripheric SC among developing countries (Paiva and de Oliveira, 2021) or the co-authorships trends on spatial science and geosciences (Vanz and Stumpf, 2012), there is a scarcity of research about how geography SC networks develop within developing regions, particularly looking at "south-south" relationships. Thus, the present study aims to explore how does these SC unfolds in the context of the geography education sub-field within Latin America, by explaining the spatial perspectives and transformations of SC in the researchers' networks during the 21st century.

Which factors influence scientific collaboration among researchers?

Researchers have studied several factors that could enhance or prevent SC. The geographic proximity has been one of the major topics addressed by scholars, as collaboration has been found to increase the closer researchers are in space (Katz and Martin, 1997; Abramo, D'Angelo and di Costa, 2009; Yan and Sugimoto, 2011; Pan, Kaski and Fortunato, 2012). The spatial proximity increases probabilities of finding colleagues, reduces the costs of collaboration and facilitates the transmission of tacit knowledge (Hoekman, Frenken and Tijssen, 2010; Bergé, 2017). Larger geographic distances often hinder scientific collaboration (Fernández, Ferrándiz and León, 2016; Yao, Qu and Tan, 2021), and even researchers production shifts towards local SC after moving to new geographic contexts (Wang *et al.*, 2019; Bernard, Bernela and Ferru, 2020).

Despite the growth of international collaboration, the level of SC tends to be greater within national borders (Hoekman, Frenken and Tijssen, 2010; Hennemann, Rybski and Liefner, 2012). Being in the same country eases the process of collaborating, as researchers have found a negative effect of SC with distance, especially when working with colleagues from other countries (Capelli and Montobbio, 2016; Bergé, 2017; Quatraro and Usai, 2017). Even on international SC, short distances among countries facilitates more scientific collaboration (Csomós, Vida and Lengyel, 2020). The introduction of information and communication technologies (ICT) have reduced spatial barriers for SC, enhanced productivity, and access to knowledge (Ding *et al.*, 2010; Yao *et al.*, 2021). However, the distance between researchers still plays an important barrier for international collaboration (Hoekman, Frenken and Tijssen, 2010; Csomós, Vida and Lengyel, 2020).

Geographic proximity has been detected as a main factor for developing scientific networks (Gu and Liu, 2020), which are likely to be formed more easily within national borders because of scholar's mobility (Miguélez and Moreno, 2014). In fact, geographic closeness increases the probability of SC and networking (Bergé, 2017)

The proximity between institutions who share similar habits, rules, and cultural norms encourages SC among researchers (Boschma, 2005; Fernández, Ferrándiz and León, 2016; Matthews *et al.*, 2020). Some studies have suggested that the distance, bureaucracy and lack of institutional support prevents researchers of engaging in collaboration efforts (Thijs and Glänzel, 2010; Matthews *et al.*, 2020).

Another important factor influencing SC is the social proximity, where researchers engage with their peers based on previous experiences and friendship (Boschma, 2005; Fernández, Ferrándiz and León, 2016). By creating social networks for collaboration, these scientific research groups find reliable sources of partners, reducing the effect of distance barriers (Hou, Kretschmer and Liu, 2008; Bergé, 2017).

Authors like Zhang *et al.* (2018) proposed homophily, preferential attachment, and transitivity as mechanisms that facilitate SC in social networks. The homophily refers to the process in which researchers prefer to engage in collaboration with those who have similar interests, scientific approaches and specialization, profile, background, and shared knowledge (Boschma, 2005; Freeman and Huang, 2014; Fernández, Ferrándiz and León, 2016; Bergé, 2017; Yao *et al.*, 2021). Several studies pointed out that sharing a language can enhance or hinder SC in different geographic contexts (Hoekman, Frenken and Tijssen, 2010; Hwang, 2013; Munoz, Queupil and Fraser, 2016; Hou, Pan and Zhu, 2021).

The preferential attachment implies the idea that working with influential, popular, or notable researchers increases SC (Wagner and Leydesdorff, 2005; Milojevic, 2010; Zhang *et al.*, 2018; Hou, Pan and Zhu, 2021). Several studies showed that working with leading experts or recognized scientists enhances productivity, more impact, and fosters career successfulness (Klavans and Boyack, 2010; Feeney and Welch, 2014; Li *et al.*, 2019). Thus, it is not strange that transitivity also works as a mechanism for social networking among scholars, since it guides them to select specific collaborations rather than randomly choosing among researchers, increasing the benefits but also preventing others to join established research networks (Zhang *et al.*, 2018).

The present study builds on the analysis of these factors influencing SC, as it aims to provide a perspective of geographic and social networking shaping the development of collaboration among researchers. By looking at a close system of SC among Latin American researchers who published in journals within the region, the article explores how these networks of scientists are developed at the national and intra-regional level, as well as the evolution throughout time.

Research method

Data Collection

This study analyses the process of SC on geography education among researchers within Latin America from 2000 to 2019, based on the articles published in open access journals (OAJ), who have a predominant role in this region by disseminating free, peer-reviewed scientific findings (Babini and Smart, 2006, Minniti, Santono and Belli, 2018). A total of 140 OAJ were accessed by doing a multiple search including online information journals systems such as Dialnet, DOAJ, Redalyc, and Dialnet. Additionally, online queries on geography departments across Latin America allowed the identification of these journals.

The identification of geography education research involved the review of research titles and abstracts, combined with the analysis of key words related to geography education. Several articles were excluded from the study since their author's affiliation indicated that they corresponded to countries outside

the region. This decision was taken as the research purpose is to look into SC among researchers within Latin America exclusively. A list of 1744 articles were finally selected.

The research included articles from 2000 to 2019 as a way to understand SC during the century, excluding the years 2020, 2021 and 2022. The appearance of the COVID-19 might have introduced changes in the publication patterns within the region, in addition to the fact that some journals have not completed the 2021 or 2022 issues yet. Thus, articles from these years were excluded on this study. Further research could expand the topic of study by including the SC during the pandemic years.

Analyzing SC patterns in Latin America

The analysis of co-authorships in scientific publications represents a verifiable, replicable, and an easy way to analyse SC (Katz and Martin, 1997, Duque *et al.*, 2005; AlShebli, Rahwan and Woon, 2018). Following this approach, a database was developed by adding the OAJ name and country of origin, the author's name and affiliation for each article from 2000-2019, with the purpose of identifying SC patterns.

The database allowed the use of two methodological procedures to analyse the SC patterns of research in geography education in Latin America. First, a trend analysis looked into the dynamics of geography education SC of the region, showing the number of publications that correspond to single-author and multi-author papers throughout time. Then, a description of the multi-scale levels of research collaboration contributed to understand how do SC evolved in the region.

The second procedure employed social network analysis (SNA) as a method to explore the relationships of SC in Latin America. In SNA, networks are created through the interaction at different levels (e.g., among institutions) by exchanging knowledge and information (Hansen, Shneiderman and Smith, 2011; Abbasi, Chung and Hossain, 2012). The SNA provides the possibility of generating visualizations and statistical metrics, which contribute to the understanding the SC patterns through the representation of collaboration as nodes and edges (Munoz, Queupil and Fraser, 2016). By using the database information about author's name and affiliation, it is possible to gather network's metrics for researcher's SC at an institutional level.

The research approaches researcher's interactions at an institutional level using several metrics, starting with the network density, which looks at the level of connection that exists among nodes (institutions) in the network, by establishing a ratio of existing connections among nodes with the maximum possible, if all of them were connected to each other (Hansen, Shneiderman and Smith, 2011). Higher networks densities tend to represent more connectedness. Additionally, the average geodesic distance was calculated to understand how close members of a network are from each

other. Large networks tend to have lower average geodesic distances (Hansen, Shneiderman and Smith, 2011).

Another important measurement in SNA is the node's centrality, which offers details about the importance, influence or power that a researcher's institution might have in a network. Hansen, Shneiderman, and Smith (2011) proposed that centralized networks have many edges that come from few nodes, and usually represent more hierarchical structures with few actors (researchers) having a key role.

Several metrics can be applied to understand the centrality, being the degree centrality used to detect who has a central or influencing position in a network, and it is measured by counting the connections linked to a node (Hansen, Shneiderman and Smith, 2011; Woo, Kang and Martin, 2013; Munoz, Queupil and Fraser, 2016). This metric will allow to identify influential researcher's institutions in geography education on this regional network. A second metric used was the betweenness centrality, which measures how certain nodes tend to act as a bridge with other nodes, identifying facilitators within the network (Woo, Kang and Martin, 2013; Munoz, Queupil and Fraser, 2016).

The last metric used is eigenvector centrality, which measures not only the connections a node has, but also how many edges (links) their connections have with other nodes. It is an important measure as nodes with higher eigenvector centrality tend to be "well-connected" with key nodes in the network. It is argued that being connected to key nodes is critical for SC (Hansen, Shneiderman and Smith, 2011). The calculation of the SNA metrics involved the use of the GEPHI software 0.9.2.

The analysis employed a multi-temporal perspective to analyse both the general trend analysis as well as the SNA. Cascante-Campos (2021) research proposed that the development and production of geography education research in Latin America can be divided in three different phases. There was an initial and incipient development of the sub-field from 2000 to 2011, followed by a sharped increase in academic production from 2012 to 2017. An even steeper development of research occurred from 2018-2019, a period where 25% of all scientific articles in the region were published. The current study adopted the same periodization, with the purpose of analysing the development of SC among researchers in Latin America, as well as the explanation of the global pattern in the region (2000-2019).

Results and discussion

General trend analysis

The analysis of authorship (Table 1) revealed that the percentage of articles published through co-authorship is slightly higher than those single-authored. There was a change during the period 2012-2017, where co-authorships surpassed single-author publications. Specifically, the multi-author

publications have been higher in Latin American OAJ since 2015 (Figure 1). While only four out of ten publications in the first decade of the century were the result of SC, two out of three articles were the result of collaboration among scholars in 2018-2019.

Table 1. Types of authorship in geography education articles published in Latin American OAJ from 2000-2019

Period	*Single-authored*	*Multi-authored*
2000-2011	287 (59.4 %)	483 (40.6 %)
2012-2017	395 (47.5 %)	436 (52.5 %)
208-2019	140 (32.6 %)	290 (67.4 %)
Total	822 (47.1 %)	922 (52.9 %)

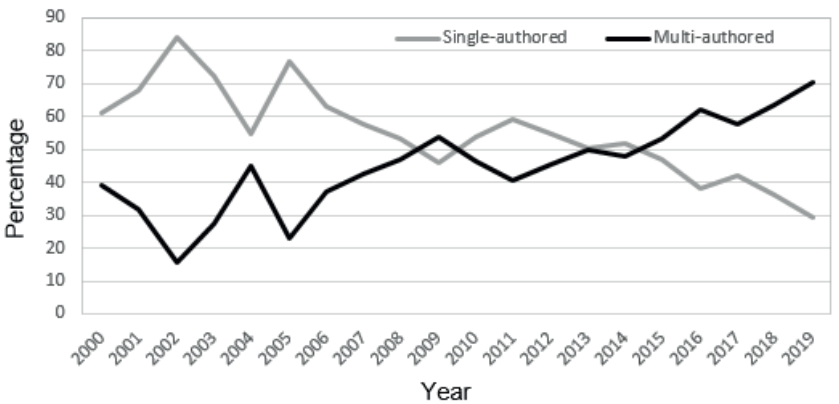

Figure 1. Temporal authorships trends of research within the region.

A more in-depth review of the different levels in which co-authorship occur (Table 2), revealed that the majority of publications were the result of the SC between two authors, followed by three-author's publications, and to a lesser extent, four scholars or more. These results have been found to be consistently similar throughout the period of study, suggesting a pattern of SC among few authors.

Co-authored publications occurred at three different scales. It was found that 98.4% of all studies corresponded within national borders, either produced by researchers working at the same institution or, collaboration among scholars from different institutions within the same country, or researchers working in the same country. The remaining 1.6% corresponded to intra-regional SC among authors from two or more countries of the region.

Table 2. Co-authored research within Latin America from 2000-2019

Period	*Two authors*	*Three authors*	*Four authors or more*
2000-2011	132 (67.35%)	44 (22.45%)	20 (10.2%)
2012-2017	288 (66.06%)	113 (25.92%)	35 (8.02%)
2008-2019	194 (66.9%)	75 (25.86%)	21 (7.24%)
Total	614 (66.6%)	232 (25.16%)	76 (8.24%)

Social Network Analysis: Institutional perspective

The figure 2 shows the institutional networks of SC in geography education research from 2000-2019. These networks show an increasing level of complexity on interactions throughout the period of study. Some institutions play a key role in the research development, but at the same time the networks exhibit specific clusters among many universities. The Table 3 shows the network properties of institutional SC in the region. The number of universities (nodes) and their interactions (links) showed an increasing trend through the different periods. While certainly the number of nodes and links from 2012-2017 were higher than 2018-2019, the latter covers only two years, suggesting an increasing number of co-authorships and interactions in the region.

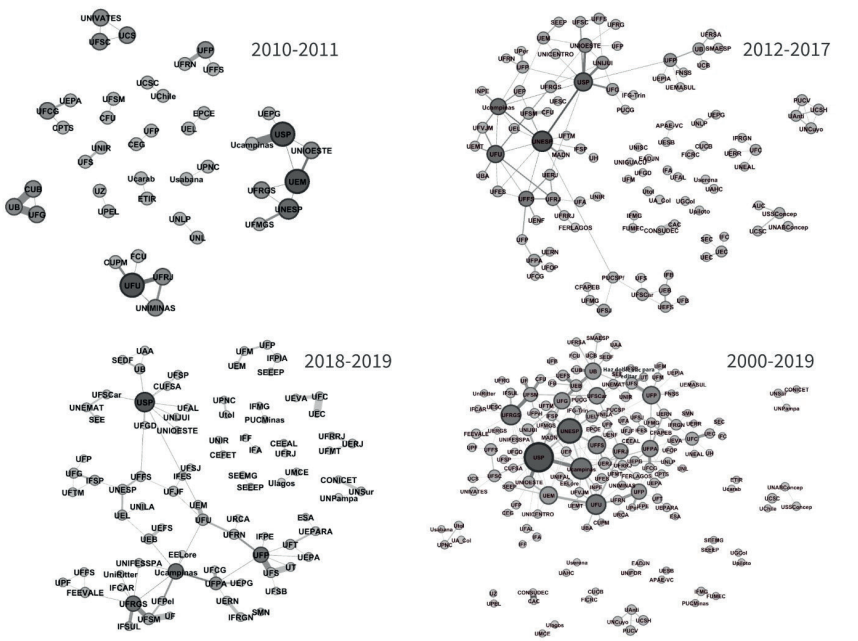

Figure 2. Networks of institutional geography education SC within the region.

The total network density value indicates that only 1.7% of all possible connections among institutions are actually linked. It was expected that the network density values increased through the different phases as the number of researchers increased and became more interconnected.

The increase of joint research did not translate into a more connected network as we shifted from 3.5% (2000-2011) to 2.1% (2012-2017) and 2.2% (2018-2019) of all possible connections actually linked. The results from the average geodesic distance suggest that although the network grew overtime, it still has the characteristic "small-world" where authors tend to be linked closely.

Table 3. Network properties of institutional SC in Latin American geography education research

Properties	*2000-2011*	*2012-2017*	*2018-2019*	*2000-2019*
Number of nodes	43	104	86	161
Number of links	33	114	86	220
Network density	0.035	0.021	0.022	0.017
Average geodesic distance	1.61	4.07	4.69	3.94

Table 4. Centrality measures for the Latin American institutional SC in geography education research

Degree centrality		*Betweenness centrality*		*Eigenvector centrality*	
University of São Paulo	20	University of São Paulo	1	University of São Paulo	0.227
Paulista State University	16	Paulista State University	0.879	Paulista State University	0.104
Campinas State University	13	Campinas State University	0.659	Paraíba Federal University	0.101
Uberlândia Federal University	12	Uberlândia Federal University	0.585	Fluminense Federal University	0.097
Rio Grande do Sul Federal UniversitY	12	Fluminense Federal University	0.853	Campinas State University	0.0096

The centrality measures (Table 4) for institutional SC revealed the core positions of University of São Paulo, Paulista State University, and Campinas State University. These three institutions have a high influence in the network structure and an important role linking with other nodes, as part of the process of connecting with clusters of researching universities. Moreover, the eigenvector centrality suggest that they also have a wider reaching influence

in the collaboration networks, this means that they have a higher network influence at a macro-scale, being this particularly interesting as the three universities are specifically located in the Brazilian state of São Paulo.

The research findings should be interpreted in several ways. First, Latin American geography education research confirmed the trends of increasing levels of SC among scholars mentioned in different studies around the globe. There was a transition towards more co-authorship in the region since 2015. However, the study also revealed the prevalence of intra-national collaboration, similar to global trends.

The results confirm that the geographic proximity represents a fundamental factor defining the development of SC in geography education research in Latin America. The vast majority of collaborative studies are published by researchers working at a local or national scale. The scarcity of intra-regional studies, the existence of an institutional proximity in SC, but limited to the local-national level, and the fact that the centrality measures pointed out what Cascante-Campos (2021) found as the predominance of Brazilian universities in geography (being many of them very close in space), led to the conclusion that a regional approach to SC in geography education research has not developed yet. The national borders constitute a factor that promotes research locally but hinders intra-national collaboration, where some key universities exert greater influence in the development of geography education research and SC.

Conclusions

The SC analysis pointed out some findings that could have meaningful implications for the development of the Latin American geography education research. Since higher levels of SC have been identified in recent years, the most important task for the scholarly community is necessarily to promote more research cooperation among the region's countries. Although some studies have suggested the effect that local funding schemes have for promoting intra-national research (Glänzel and Schubert, 2005; Chinchilla *et al.*, 2010; Bergé, 2017), it is worth exploring innovative and technological ways to address these limitations (Ding *et al.*, 2010; Yao *et al.*, 2021) with the purpose of overcoming the barrier that geography imposes in the growth of intra-regional SC in Latin America.

On this regard, it would be useful to consider the research findings about the role that key institutions exhibited in the SNA of the regional SC. Expanding intra-regional cooperation levels in geography education might be faster and easier to occur if those who have a key position in the network engage in projects to promote a more regional collaboration. A geography education research network as shown in this study should not be seen as a "geographical" weakness in the development of the field. There are certain institutional nodes in the network where geography education researchers could work as leaders in the field, helping authors from other institutions and

countries in the process of engaging in research, promoting new ideas that could be shared, improved or debated by scholars in the region. In this way, the current structure of the geography education research in Latin America offers an opportunity for continue seeing a more diverse perspectives about co-authoring in the sub-field in the near future.

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