






Citation and co-authorship networks on the education of teachers who teach mathematics: An analysis of the IX SIPEM

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ABSTRACT

Background: The education of teachers who teach mathematics is a research theme within the field of mathematics education. This theme has grown considerably in recent years, enabling discussions and reflections among researchers; therefore, it becomes relevant to understand how they relate within the academic community. **Objectives:** From a phenomenological perspective, we inquire: What shows itself from the citation and co-authorship networks derived on the basis of the texts published in the proceedings of the IX SIPEM on the education of teachers who teach mathematics? **Design:** We adopted a qualitative phenomenological approach, from which modes of proceeding specific to the investigated phenomenon emerged. **Data source:** The analysed sources comprised 39 texts on the education of teachers who teach mathematics published in the Seminar proceedings. **Data production and analysis:** The data were produced with the aid of a spreadsheet containing the names of the authors/co-authors of the analysed texts and the respective names of the authors/co-authors cited in those texts. This spreadsheet was imported into VOSviewer to generate networks, which were subsequently analysed and interpreted. **Results:** A general citation and co-authorship network emerged, consisting of 1,004 authors/co-authors, organised into 20 clusters, which represent groupings and authorship relationships among these authors/co-authors. **Conclusions:** The analysis of the networks reveals a dispersion of cited authors, possibly due to the thematic diversity. It also highlights a concentration of citations among influential and “classical” authors in teacher education, indicating that the theme is well established in both national and international contexts.

Keywords: Citation Networks; Teacher Education; Mathematics Education; Phenomenology; VOSviewer.

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Redes de citações e coautoria sobre formação de professores que ensinam matemática: Uma análise do IX SIPEM

RESUMO

Contexto: A formação de professores que ensinam matemática é uma temática de investigação inserida no campo da educação matemática. Essa temática tem crescido consideravelmente nos últimos anos, possibilitando discussões e reflexões entre os pesquisadores e, por isso, torna-se relevante compreender como eles se relacionam na comunidade acadêmica. **Objetivos:** Interrogamos, segundo uma visão fenomenológica: O que se mostra das redes de citações e coautoria constituídas a partir dos textos publicados nos anais do IX SIPEM sobre a formação de professores que ensinam matemática? **Design:** Assumimos uma abordagem qualitativa fenomenológica, da qual emergiram modos de proceder próprios ao fenômeno investigado. **Fonte de dados:** As fontes analisadas foram 39 textos concernentes à formação de professores que ensinam matemática publicados nos anais do Seminário. **Produção e análise de dados:** Os dados foram produzidos com auxílio de uma planilha eletrônica, na qual consta os nomes dos autores/coautores dos textos analisados, e os respectivos nomes dos autores/coautores referenciados nesses textos. Essa planilha foi inserida no software VOSviewer, o qual gerou as redes que foram analisadas e interpretadas. **Resultados:** Emergiu uma rede de citações e coautoria geral formada por 1004 autores/coautores, organizados em 20 *clusters*, que representam agrupamentos e relações autorais entre esses autores/coautores. **Conclusões:** A análise das redes revela a dispersão de autores citados, possivelmente devido à diversidade da temática. Evidencia-se, também, uma concentração de citações em autores considerados influentes e “clássicos” no contexto da formação de professores que ensinam matemática, evidenciando que a temática se encontra consolidada no cenário nacional e internacional.

Palavras-chave: Redes de Citações; Formação de Professores; Educação Matemática; Fenomenologia; VOSviewer.

INTRODUCTION

The education of teachers who teach mathematics¹, in its different modes, conceptions, and theorisations, is a central theme² in the vast field of

¹ When we refer to teachers who teach mathematics, we are considering all those who teach the subject, including those who, although not specifically trained in mathematics, also teach it, such as pedagogy licensees.

² In this text, we define the words *subthemes*, *theme*, *area*, and *field* following a hierarchy. The word *subtheme* refers to a study embedded within a *theme*, which, in turn, refers to a specific study within an *area* and a *field*. Regarding the word *area*, we will use it as a focus of a *field*. And the word *field* refers to the broader study. For example, the professional development of the teacher who teaches mathematics is a

mathematics education (Ponte, 2023). Research on the subject has grown considerably in recent decades (Souza & Klüber, 2025), contributing to the consolidation of the education of teachers who teach mathematics as a specific research theme. However, the process occurred gradually, supported by the researchers' reflections (Nacarato & Paiva, 2013).

Two decades ago, Fiorentini et al. (2002) presented a balance of academic production on the education of teachers who teach mathematics over 25 years (1978–2002), evidencing the expansion of studies aimed at understanding what teachers think about their own education, practice, and professional development. The study also pointed to the diversification of theories and methodologies in research and to the strengthening of the education of teachers who teaches mathematics as an autonomous field of research within mathematics education.

In this context of expansion, the academic community began to recognise the importance of spaces for socialisation and for discussing research. Nacarato and Paiva (2013) document the creation of the International Seminar on Research in Mathematics Education (Seminário Internacional de Pesquisa em Educação Matemática—SIPEM) and its role as a milestone in this expansion movement, enabling researchers to share results, form partnerships, and develop joint investigations. According to the authors, working group 07 (Grupo de Trabalho 07—GT 07) was founded during the first SIPEM in 2000, specifically aimed at the education of teachers who teach mathematics, further strengthening the debate and research on the subject.

According to Nacarato and Paiva (2013), one of the major milestones of the first SIPEM, in addition to the constitution of the working group itself, was the identification of the main researchers in the education of teachers who teach mathematics and their respective institutions. The authors point out that, in the first two seminars, the studies focused mainly on master's and doctoral research, linked to graduate programs and higher education institutions.

Almost two decades later, when analysing research on the education of teachers who teach mathematics published in the proceedings of SIPEM, Souza and Klüber (2025) found that research on the theme is, for the most part, excerpts from larger studies such as doctoral and master's theses. Also,

sub-theme of the *theme* “education of teachers who teach mathematics”, which is situated in the “teacher education” *area*, which, in turn, is embedded in the “mathematics education” *field*.

according to Souza and Klüber (2025), these investigations are predominantly carried out in co-authorship (with a student and a research advisor/co-advisor) or within research groups.

Given these aspects of research on the education of mathematics teachers and their respective researchers, we examine the scientific relationships among these communities to understand the current state of this theme. Thus, considering that research on the education of teachers who teach mathematics has had a community established in the field of mathematics education for some decades, in view of the working group GT 07 of the Brazilian Society of Mathematics Education (Sociedade Brasileira de Educação Matemática—SBEM), it is relevant to go to the phenomenon of citation networks in search of understanding them in their own dynamics. Thus, our research question is: What shows itself from the citation and co-authorship networks derived on the basis of the texts published in the proceedings of the IX SIPEM on the education of teachers who teach mathematics?

We take a phenomenological view of research in search of understanding the phenomenon questioned in its different ways of showing itself and, therefore, without any *a priori* assumptions as to its content. Thus, we focus on the phenomenon: networks of citations and co-authorship and how they are shown in the context of the education of teachers who teach mathematics, open to what emerges from the dynamics of the relationships between the authors/co-authors of the texts and authors/co-authors referenced in these texts published in the proceedings of the IX SIPEM.

We chose the SIPEM proceedings because it is an event within our lived horizon, where participants discuss and debate Brazilian research in the field of mathematics education, thereby making it even more widespread. Thus, we turn our attention to the works submitted to GT 07 of IX SIPEM, carried out in 2024 in Natal (RN), Brazil, seeking to understand the networks of citations and co-authorship of the education of teachers who teach mathematics.

Our research question also asks us to present to the reader studies and understandings about networks of citations and co-authorship, not as a theoretical reference, but as an aspect of our research region that requires explanation. It also asks us to clarify the methodological trajectory and the analysis and interpretation of emerging networks. Therefore, in addition to this introduction, this article explains aspects related to citation networks and co-authorship, the methodological approach and the procedures, as well as analyses and interpretations of the emerging networks, and offers some considerations.

CITATION AND CO-AUTHORSHIP NETWORKS

Some studies on networks of citation and co-authorship were developed in the context of the social sciences to understand and analyse the relationships and interactions among actors, whether people or organisations.

Among these studies, authors such as Lima (2011), Ruas and Ferreira (2016), Higgins and Ribeiro (2018), and Patriarca (2022) present the social network analysis (SNA), a way of investigating how the interaction among individuals, groups, institutions, or organisations occurs; i.e., the focus of SNA is the study of the relationships among social actors.

According to Higgins and Ribeiro (2018), SNA uses matrix algebra and the language of graph theory, developed by mathematician Leonard Euler, as a tool to describe the morphology of social networks, allowing for the comparison of networks and the identification of patterns and regularities, to constitute a set of quantitative methods applied to relational data. In addition, the SNA uses the qualitative method for the analysis of connections, which allows for carrying out “[...] interpretative and constructivist foundations that understand the relationships from the point of view of the actors within the networks” (Patriarca, 2022, p. 15).

The theoretical-methodological approach of SNA, as presented in a study by Lima (2011), served as a basis for investigating the structural evolution of scientific co-authorship networks formed by a group of researchers in a postgraduate program. The main results indicate that the set of dominant actors in the networks is, for the most part, composed of teachers and tends to remain stable over the years.

In the study by Ruas and Ferreira (2016), the SNA was used in conjunction with the citation analysis (CA) in order to identify the most referenced authors in publications that address the field of scientific education in the portal of journals of the Coordination for the Improvement of Higher Education Personnel (Portal de Periódicos da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—CAPES). The verification and analysis of the citation network were carried out using UCINET to identify the most-cited authors in the network, thereby indicating their visibility and influence in the field of scientific education. The study demonstrated the relevance of SNA in conjunction with CA for mapping and analysing collaboration between authors and the main references of a theme or field of knowledge.

In these studies, it is noteworthy that citation networks and co-authorship allow us to investigate collaboration among researchers within a given academic community or in relation to a specific theme. What differentiates these networks is the form of relationship that the actors represent in scientific production. The citation network represents the relationships between citing and cited actors in a given collection, such that its nodes (vertices) represent articles, authors, or journals, and its lines represent the citation relationships among these actors (Ruas & Ferreira, 2016). The co-authorship network refers to the direct collaboration among two or more authors who published a work together; the nodes (vertices) of the network usually represent individual authors, and a line connects two authors if they have co-authored one or more articles (Newman, 2004).

Given the above, we note that the analysis of networks of citations and co-authorship may have started in the context of the social sciences, but expanded as a possibility to understand relationships in different fields of knowledge, opening a horizon for investigations concerning the networks of citations and co-authorship in the field of knowledge of mathematics education. It is worth noting that although it may address quantitative aspects, research on the networks developed in this field primarily adopts a qualitative approach that seeks to investigate, understand, and interpret the collaborative relationships among researchers across their different aspects.

The research by Santos (2021) and Santos et al. (2023) in the context of mathematics education sought to investigate, through co-authorship networks, publications in Brazilian journals of mathematics education. These investigations aimed to identify the groups of authors who contribute most to the publications of the journals and, consequently, to the dissemination of knowledge in the field of mathematics education, as well as the most discussed topics in those publications. The authors state that studies of co-authorship networks have been used to identify and map scientific collaborations among researchers and research programs to disseminate and strengthen scientific production. In addition, “[...] the existence of an interconnection of ideas between authors and co-authors can generate a conceptual identity between them, based on exchanges of thought and sharing of experiences” (Santos et al., 2023, p. 394).

Other research concerning the networks of citations and co-authorship in the context of mathematics education was developed by Klüber (2023), Garcia and Klüber (2024), Corassa et al. (2025), and Stahlhofer and Klüber (2025), within the scope of the productivity project entitled “Co-authorship

networks in the field of research of mathematical modelling and teacher education” (Redes de coautoria no campo de pesquisa da modelagem matemática e formação de professores), approved by the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico—CNPq) n. 24.473.345-0. This project is being developed by the members of the research group Phenomenological Investigation in Mathematics Education (Investigação Fenomenológica na Educação Matemática—IFEM), given the interest of the group leader and other members in examining how they are constituted and what the networks of citations and co-authorship of the productions reveal among researchers in the area of mathematical modelling and teacher education in mathematics education.

Klüber (2023) sought to investigate what the citation networks of the IFEM research group’s publications on teacher education and mathematical modelling reveal. The networks were elaborated with the help of Gephi network analysis software to show that the circulation of texts initially represents an intracollective movement in orientation works and, secondarily, a less pronounced intercollective movement that resonates in texts by other authors in the community. According to the author, the analysis and interpretation carried out in the IFEM group allow us “[...] to look more comprehensively at challenges, perspectives, and values in research on teacher education[...]” (Klüber, 2023, p. 13).

Garcia and Klüber (2024) analysed the direct and indirect citations of a prominent reference in the works presented at the 2022 Meeting of Modelling in Mathematics Education of Paraná (Encontro Paranaense de Modelagem em Educação Matemática). This investigation allowed us to identify, through citations, the main contributions of the prominent reference to the advancement of mathematical modelling area, such as defining it as a pedagogical alternative.

Corassa et al. (2025) investigated what the citation networks emerging from scientific communications published at the XII National Conference on Modelling in Mathematics Education (Conferência Nacional sobre Modelagem na Educação Matemática—CNMEM) reveal. By analysing and interpreting the networks, the researchers identified a wide dispersion of citations among the referenced authors, together with a predominance of authors in the SBEM mathematical modelling GT10, which constitute nuclei of citations and collectives of thought in the mathematical modelling community.

Stahlhofer and Klüber (2025) investigated co-authorship networks in scientific communications across all editions of the CNMEM and showed that

co-authorships are centred on internal relations within the research groups, with the main authors of the network being either leaders or participant members. It was also revealed the predominant authors across productions throughout all CNMEM editions (Stahlhofer & Klüber, 2025).

Still researching networks of citations and co-authorship in the context of mathematics education, Staub et al. (2025) investigated the formation of a collective of thinkers around lesson study (LS) in mathematics. The authors analysed citation networks in research using that formative process in Mercosur countries (Argentina, Brazil, Paraguay, and Uruguay) based on articles published in the proceedings of the I International Seminar on Lesson Study in Mathematics Teaching (Seminário Internacional de *Lesson Study* no Ensino de Matemática—SILSEM). The analysis of authorship and citations was conducted by constructing a graph in Gephi. It was evidenced that Brazil is the only Mercosur country that publishes works on lesson study, so that some small groups present themselves as references and self-references on the subject in the region. Moreover, the study unveiled “[...] the need to establish co-authoring and collaboration networks beyond the groups themselves” (Staub et al., 2025, p. 21).

These investigations concerning the mentioned networks of citations and co-authorship reveal that the theme is relatively recent in the context of mathematics education in Brazil. In addition, we did not find, in a non-exhaustive review, research on citation networks and co-authorship that specifically addresses the education of teachers who teach mathematics. Therefore, investigating these networks in the education of teachers who teach mathematics opens the possibility of mapping and understanding scientific collaborations among researchers in this field, thereby informing discussions and advancing the academic community.

METHODOLOGICAL APPROACH AND WAYS OF CONDUCTING RESEARCH

To understand the networks of citations and co-authorship in the education of teachers who teach mathematics within mathematics education, and considering the proceedings of the IX SIPEM, we adopted a qualitative approach, grounded in a phenomenological view, to examine what is revealed in the phenomenon under investigation.

Showing up, in phenomenology, “[...] takes place in the attentive and rigorous search of the subject who questions and seeks to see beyond appearance, insisting on the search for the characteristic, basic, essential of the

phenomenon (what is shown to the subject)” (Bicudo, 1994, p. 18). Thus, showing oneself does not mean that the phenomenon is an object placed in the external world with its own life, to be observed or manipulated by a subject. However, it means that the “[...] phenomenon is what is shown in the act of intuition performed by an individually contextualised subject, who looks towards what is shown attentively and who perceives that which is shown [...]” (Bicudo, 2011, p. 30). Thus, phenomenon and subject are not considered separate; on the contrary, they are united in this very act of appearing (Bicudo, 2011).

In this context, the phenomenological research approach presents itself as a radical way of thinking, which “[...] means that it is based on the researched phenomenon and that, through its method, it does not put any *a priori* factor as to the content of the phenomenon” (Giorgi, 2010, p. 387-388). Thus, we seek to understand what the phenomenon reveals in its different modes of manifestation, in order to suspend pre-established beliefs. Therefore, although formal theories investigate networks of citations and co-authorship, such as the analysis of social networks and others mentioned in the previous section, we do not use them as a theory of analysis, although we can, *a posteriori*, dialogue with them.

Thus, our research question is: What shows itself from the citation and co-authorship networks derived on the basis of the texts published in the proceedings of the IX SIPEM on the education of teachers who teach mathematics? The questioning guides all the research developed, as we constantly dialogue and reflect with it, seeking to clarify the phenomenon under question. This “[...] movement made to deal with this search helps us focus on *what*, contributing to our thinking reflexively about *how* to proceed to correspond to what was questioned” (Bicudo, 2011, p. 23, emphasis added).

Therefore, the ways of carrying out the research, from a phenomenological perspective, derive from the reflective movement in relation to the question posed and outline the path taken to clarify the phenomenon. Thus, our question asks us to examine the texts on the education of teachers who teach mathematics published in the proceedings of the IX International Seminar on Research in Mathematics Education (SIPEM) to identify and interpret emerging networks of citations and co-authorship. When searching the IX SIPEM website, we found 39 texts on the theme to be analysed.

The process of constitution, analysis, and interpretation of emerging networks was inspired by the research carried out by Corassa et al. (2025), in which the authors investigated the citation networks emerging from scientific

communications published at the XII National Conference on Modelling in Mathematics Education, which were constituted and interpreted with the aid of spreadsheets and generated in the network analysis software VOSviewer.

VOSviewer was developed by Nees Jan Van Eck and Ludo Waltman in 2010 at the Centre for Science and Technology Studies, Leiden University, the Netherlands. It is free software available online or for download that can be used to plot and visualise bibliometric networks, such as those between authors or journals, to map connections and relationships using data such as citations, co-authorship, and co-citation. These networks can be visualised graphically in several ways, focusing on various aspects (Van Eck & Waltman, 2010; Perianes-Rodriguez et al., 2016).

According to the authors, the software can be used to generate bibliometric networks through data imported from bibliographic databases such as Web of Science and Scopus, in which the indexed searches have DOI (Digital Object Identifier), so that, in these bases, it is possible to automatically export a CSV (Comma-Separated Values) file that supports the software's functionalities, facilitating the analysis of the networks. However, VOSviewer does not have the functionality to automatically import publication data for events that were not published according to indexing database rules. Thus, it is necessary to perform this process manually, using spreadsheets for the organisation and importing data into the software (Corassa et al., 2025).

The software must *be-with-the-researcher*, as it is not a mere tool that assists the researcher in the research process. It is necessary to consider that “[...] the movement of production, analysis, interpretation, and reflection is carried out by the *researcher-with-the-software*” (Ramon & Souza, 2025, p. 31). This movement, carried out from a phenomenological perspective, shows that the software is not disconnected from the researcher, but constitutes an extension of their own experience of *being-with-the-software* (Klüber, 2025). In this sense, “[...] the software is part of the researcher's body in the phenomenological sense, as it is a means by which the relationship between the researcher and the data develops” (Mutti, 2025, p. 27).

Therefore, in our research, we do not use the technological resource as a movement external to research, but rather as a phenomenological movement of investigative experience, which explains how data are produced, analysed, and interpreted, seeking to clarify the phenomenon under investigation.

The first step for data production and the constitution of networks of citations and co-authorship was to understand how the phenomenon appears in

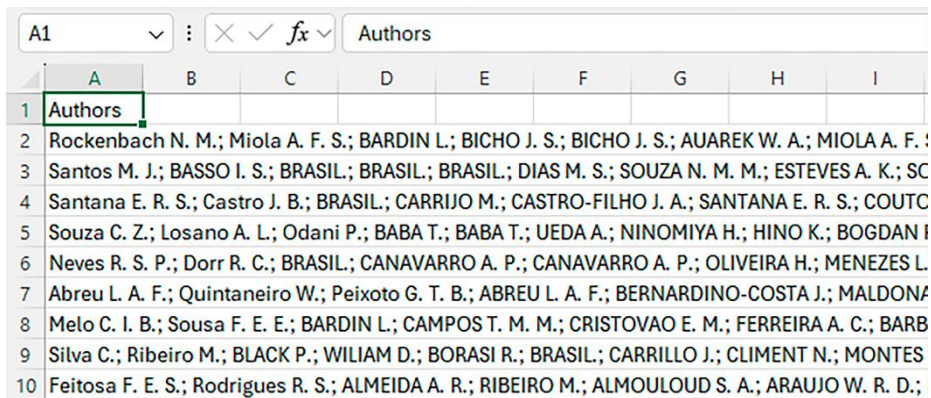
relation to what the software offers, which requested the preparation of an electronic data entry spreadsheet of the CSV type to be inserted in the software, containing the names of the authors/co-authors of the analysed texts and the respective names of the authors/co-authors referenced in these texts. This data was organised in a column with 40 rows, named ‘*Authors*’ (in English language), since the software performs the correct reading of the columns only when they are named in English. In each subsequent line, the name of the author/co-author of the text (in lowercase) and the respective authors/co-authors referenced in the same text (in capital letters) were arranged, separated by semicolons, as shown in Figure 1. We emphasise that the distinction between lowercase and capital letters was designed to organise and differentiate the authors of the texts and their respective referenced authors in the spreadsheet; however, the software does not make this distinction when presenting the networks.

According to Corassa et al. (2025), manually producing and organising data in a spreadsheet requires extensive effort and attention. This is because it is necessary to examine each text to identify and extract the name of the author/co-author and the respective referenced authors/co-authors, carefully and attentively organising these names on the lines of the spreadsheet, and checking for typos. Each divergent score interferes with the result, as well as divergences in the names of the authors/co-authors.

Thus, it was necessary to remove all the accents of the names, as well as the prepositions, such as “*dos*” and “*das*” [of/from], leaving only the initials of these names. In addition, we conducted data validation to ensure all names are unique and consistent. For example, the author João Pedro da Ponte appeared in some texts as Ponte J. and in others as Ponte J. P.; thus, it was necessary to standardise the author’s name (label) in all lines of the spreadsheet.

Figure 1

Example of a data entry spreadsheet in VOSviewer software



	A	B	C	D	E	F	G	H	I
1	Authors								
2	Rockenbach N. M.; Miola A. F. S.; BARDIN L.; BICHO J. S.; BICHO J. S.; AUAREK W. A.; MIOLA A. F. :								
3	Santos M. J.; BASSO I. S.; BRASIL; BRASIL; BRASIL; DIAS M. S.; SOUZA N. M. M.; ESTEVES A. K.; SC								
4	Santana E. R. S.; Castro J. B.; BRASIL; CARRIJO M.; CASTRO-FILHO J. A.; SANTANA E. R. S.; COUTC								
5	Souza C. Z.; Losano A. L.; Odani P.; BABA T.; BABA T.; UEDA A.; NINOMIYA H.; HINO K.; BOGDAN I								
6	Neves R. S. P.; Dorr R. C.; BRASIL; CANAVARRO A. P.; CANAVARRO A. P.; OLIVEIRA H.; MENEZES L								
7	Abreu L. A. F.; Quintaneiro W.; Peixoto G. T. B.; ABREU L. A. F.; BERNARDINO-COSTA J.; MALDONA								
8	Melo C. I. B.; Sousa F. E. E.; BARDIN L.; CAMPOS T. M. M.; CRISTOVAO E. M.; FERREIRA A. C.; BARB								
9	Silva C.; Ribeiro M.; BLACK P.; WILLIAM D.; BORASI R.; BRASIL; CARRILLO J.; CLIMENT N.; MONTES								
10	Feitosa F. E. S.; Rodrigues R. S.; ALMEIDA A. R.; RIBEIRO M.; ALMOULOU S. A.; ARAUJO W. R. D.;								

After preparing the data entry spreadsheet, we imported it into VOSviewer to proceed with the analysis of emerging networks. This process was carried out through the following steps: 1) Open the software window³, choose the *Create* functionality; 2) Choose the *Create a map based on bibliographic data* option; 3) Choose the *Read data from bibliographic database files* option; 4) Choose the *Dimensions* option and insert the CSV data entry spreadsheet; 5) Uncheck the *Ignore documents with a large number of authors* option, aiming to analyse all texts; 6) Check the *Finish* option. In the last step, the software allows selecting a minimum number of documents or citations per author.

Through this movement of production, organisation, and data insertion, the software generates the emerging networks graphically, providing analysis and interpretation of different aspects. In the next section, we will present graphical images of the networks, describing the different aspects analysed in these images, such as the number of authors, the meaning of the groupings, and the relationships between them.

³The software was downloaded through the link: <https://www.vosviewer.com/download>.

clusters are closer to the authors/co-authors, while the more isolated clusters are farther away.

The network shown in Figure 2 corresponds to an analysis of citations, with a minimum of 1 document per author/co-author, to present the clusters and all relationships among authors/co-authors cited in at least one text of the analysed corpus.

The circles represent the cited authors/co-authors, so the size of the circle indicates the frequency of citations. For example, in Figure 2, the blue circle representing Fiorentini D. is larger than the purple circle representing Nacarato A. M., which means that the former was mentioned more frequently in the texts than the latter.

Another aspect to be analysed concerns the lines, which represent the co-citation relationships among authors/co-authors. This relationship occurs when these are cited together in the same text/document. The colours and thickness of the lines that establish the relationship among these authors/co-authors may be more intense or weaker, indicating the intensity of these co-citation relationships. This relationship can be better visualised in Figure 3, which presents an analysis of citations, with a minimum of 5 documents per author/co-author, with emphasis on the author Ponte J. P. In this figure, it is possible to see that the line linking Ponte J. P. and Fiorentini D. is more intense than the others, indicating that these authors are often cited together in the analysed texts.

The choice of a minimum number of documents per author is justified by issues of better visualisation in the software and focus on the analysis, since choosing the number five, for example, will include only the authors/co-authors who were cited in at least five documents, allowing the analysis to focus on the relationships among the most-cited researchers in the analysed documents. If we choose number two, for example, the network may become dispersed, making careful analysis difficult.

Figure 3

Network of citations and co-authorship of authors with a minimum of five documents

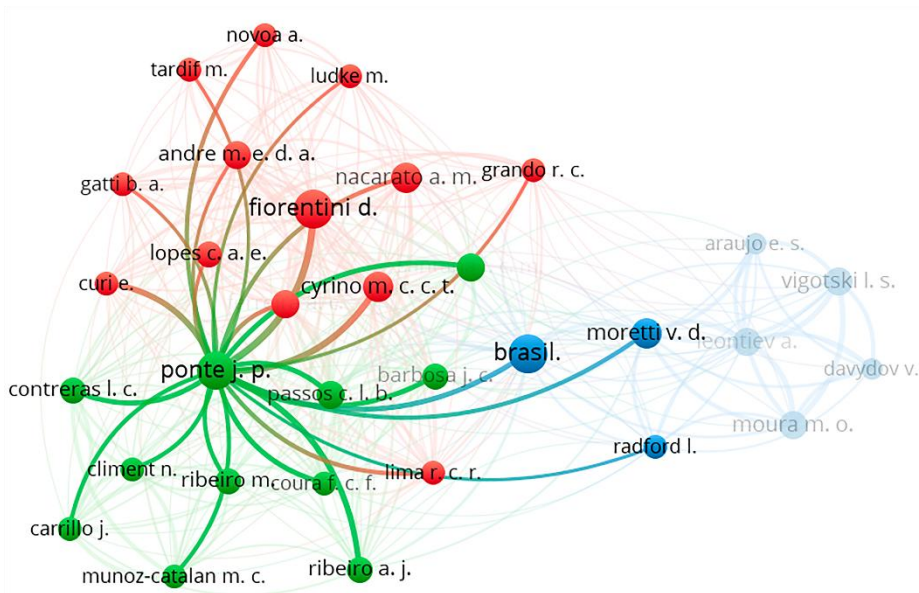
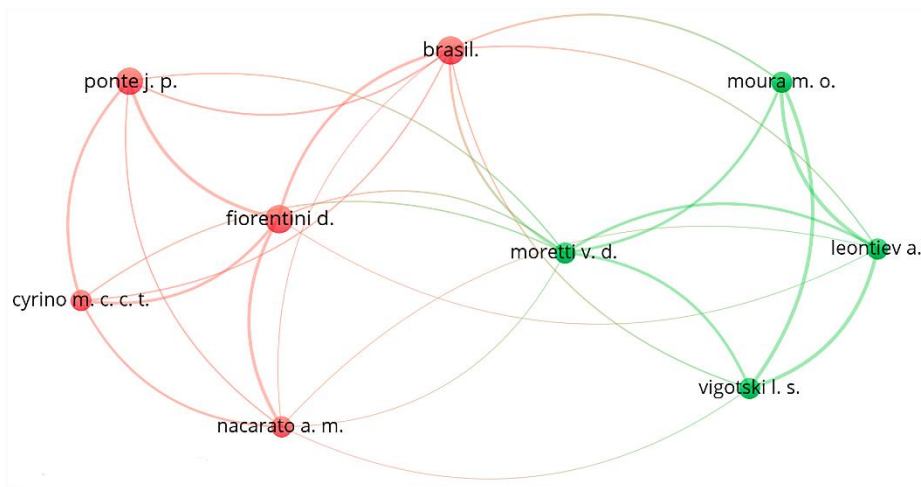


Figure 3 presents a network formed by 32 authors/co-authors, organised into three clusters. By analysing the confluences provided by the software, using the mouse cursor to highlight an author, as shown in Figure 3, we could examine scientific collaborations among researchers and discuss their influence on the research theme of the education of teachers who teach mathematics.

Another analysis considered citations, with a minimum of eight documents per author/co-author, as shown in Figure 4, resulting in a network of nine authors/co-authors organised into two clusters, showing relationships of proximity and theoretical affinities among the main researchers cited in the analysed corpus.

Figure 4

Network of citations and co-authorship of authors with a minimum of eight documents



Regarding the analysis, we present Table 1, which shows the relationship between the number of authors/co-authors and the minimum number of documents per author/co-author in VOSviewer. For example, when choosing a minimum of 2 documents per author/co-author, the analysis yields 169 authors/co-authors, i.e., they are cited in at least 2 of the analysed documents. In addition, Table 1 shows the number of clusters formed for varying minimum document counts per author/co-author. For example, when we chose a minimum of two documents per author/co-author, five clusters were formed.

Table 1

Relationship among the number of authors/co-authors and clusters according to the choice of the minimum number of documents per author in the VOSviewer software

Minimum number of documents per author/co-author	Number of authors/co-authors	Number of clusters
1	1004	20
2	169	5
3	82	4

4	51	4
5	32	3
6	18	3
7	13	2
8	9	2
9	3	1
10	3	1
11	3	1
12	3	1
13	3	1

Regarding the analysis process carried out in the VOSviewer software, we explained that this tool enabled us to go beyond simple visualisation of images and patterns, attributing meanings and reflecting on them. “In this process, the analysis carried out is not limited to the *software or to what it presents in terms of images and networks*, but involves, for us, a reduction movement conducted by the researcher [...]” (Silva & Klüber, 2025, p. 10). In this reduction movement, we seek to interpret the images beyond the visual and, through them, explain meanings that clarify what is shown in the interrogated phenomenon. That said, in the next section we interpret networks from a phenomenological perspective.

INTERPRETATION OF NETWORKS AND CLUSTERS

By assuming the phenomenological stance in this research, in the search to understand and explain the networks of citations and co-authorship emerging from the data produced, we question: What shows itself from the citation and co-authorship networks derived on the basis of the texts published in the proceedings of the IX SIPEM on the education of teachers who teach mathematics? In this movement of seeking to answer the questioned phenomenon, from the generated images, we interpret the clusters and their relationships, and explain meanings that clarify the research question. In other words, “[...] we do not look at the appearances of the image itself, performing an empirical or analytical analysis, but we look at the phenomenon of the image in order to understand what it reveals in its different ways of showing itself” (Corassa et al., 2025, p. 12).

In this movement of understanding what is revealed, we turn our gaze to Figure 2 presented in the analysis. Although it is possible to identify the prominence of some authors, such as Ponte, Fiorentini, Nacarato, and Cyrino, as well as certain relationships among them, it is observed that the clusters are

distant; that is, the authors/co-authors cited in the works of IX SIPEM are distributed in a dispersed way.

This dispersion can also be seen in Table 1, which presents the relationship between the number of authors/co-authors according to the choice of the minimum number of documents per author/co-author in the software. By increasing the minimum number of documents, it is observed that the number of authors/co-authors and the number of clusters decrease considerably, indicating that most authors/co-authors are cited in a single document in the analysed corpus and are therefore isolated.

When we ask ourselves what dispersion (*dispersão*) means, we consult the Houaiss dictionary (2004) for its definitions. The word dispersed (*disperso*) means “spread out” (*que se espalhou*), “separated” (*separado*). But what does spread mean? In another search in the Houaiss dictionary (2004), the word spread (*espalhar*) means to spread out in several directions (*lançar-se em várias direções*). However, what does that mean? This dispersion among authors may result from the diversity of sub-themes within the theme of the education of teachers who teach mathematics.

The above may mean that, in a way, the more a given theme is studied, the more it is specialised and diversified, that is, it can be subdivided into smaller complementary sub-themes, but can, in a way, distance itself as well. Researcher Dario Fiorentini, in an interview with Maia (2023, p. 16), states that the teacher who teaches mathematics (TTM):

[...] is a field of study that has at least nine different focuses of study: (1) professional knowledge, competencies and knowings of the TTMs; (2) professional development and learning of the TTMs; (3) conceptions, beliefs, social representations and attitudes of the TTMs; (4) institutions, programs, courses, subjects and other IF and CF processes of the TTMs; (5) characteristics, performance, and conditions of the TTM; (6) educational and professional practices of the TTMs; (7) History of the TTMs; (8) TTMs’ educator; (9) identity and professionalism of the TTMs (Maia, 2023, p. 16).

Considering that the study of the TTM is the direct object of the theme *education of teachers who teach mathematics*, we understand that the distancing of the clusters may mean that these focuses are consolidating as sub-themes inserted within the theme. This distance can indicate subthemes and specific niches that bring together only researchers with theoretical affinities.

Although the analysis was carried out only in one edition of the SIPEM, this dispersion can also be represented by beginning researchers in the context of the education of teachers who teach mathematics, who may be related to their advisors and tend to produce research together with them; however, it may happen that these beginners do not remain consistent in the subject. Thus, it is important for beginning researchers to continue to disseminate their research and participate in events promoted by the community of education of teachers who teach mathematics, in order to become consistent and referenced by other researchers, since isolated production in the context of master's or doctoral degrees does not guarantee visibility (Klüber, 2023).

In Figure 2, we can also identify authors who are not mathematics education researchers, such as Vygotsky, Leontiev, Freire, and Libâneo, showing that mathematics education engages in dialogue with other authors and other fields of knowledge, such as education. This aspect aligns with what Bicudo (2013) stated, namely that mathematics education is not only a branch of mathematics or of education. According to the author, mathematics education is the “between” established between mathematics and education.

Bicudo (2013) affirms that the phenomena of mathematics education, when investigated, should resort to interdisciplinary, multidisciplinary, and transdisciplinary perspectives. In this sense, we understand that research on the education of teachers of mathematics, when drawing on authors such as Freire, Vygotsky, and Leontiev, among others, integrates several fields of knowledge; that is, it dialogues with education, psychology, and philosophy, for example.

Regarding the education of teachers who teach mathematics, Freire's theories, for example, make it possible to glimpse a process of education for a liberating teacher, critical and aware of their role in teaching beyond mathematics, with a view to constituting a critical citizen and transforming their reality (Santos, 2007). Vygotsky and Leontiev, authors of historical-cultural theory, may have been taken as a reference in education because their perspectives help to think about how to organise teaching, in addition to contributing to the teacher's understanding as a subject who develops themselves in their own work, through the dialogical relationship they establish with students and with knowledge (Moraes & Moura, 2009).

In addition to the authors mentioned above, who are not mathematics education researchers, the names of the authors Minayo and Bardin appear. Both are also recognised for their writings on methodological aspects of qualitative research. This may mean that research on teacher education is

predominantly qualitative, in line with Souza and Klüber's (2025) findings regarding the education of teachers who teach mathematics.

Regarding Figure 3 of the analysis, it is possible to identify a predominance of international authors cited in the works of IX SIPEM, including Carrillo, Climent, Contreras, Munoz-Catalan, Radford, Tardif, Novoa, and Ponte, among others. Those researchers address teacher education across its different aspects, revealing that this area is discussed and reflected from a national and international perspective, although it does not engage in conversation with foreign researchers in the context of the event itself.

From the 1980s, research on teacher education focused on teachers' thinking to consider both teaching and teachers' beliefs, conceptions, values, and experiences (Ferreira, 2003). These researches were developed mainly by international researchers, among them, Tardif and Ponte, bringing new elements to the area, such as the constitution of teachers' professional practice, the knowledge of experience and professional knowledge, marking a perspective known as "epistemology of practice", which markedly influenced Brazilian research (Nacarato, 2011), so that this trend seems to remain in the IX SIPEM citation networks.

Regarding the aforementioned international authors, it is noteworthy that, even though the Seminar is international, they did not publish in IX SIPEM, so their influence on the network occurs through citations in published texts. In this regard, it is possible to infer that the international literature influences research on the education of teachers who teach mathematics in the Brazilian context, but does not directly dialogue "in person" with Brazilian researchers, which may also indicate the absence of domestic production being exported abroad.

Another relationship to be discussed, through the analysis of Figure 3, concerns authors/co-authors such as Moretti, Nacarato, Cyrino, Lopes, Barbosa, Coura, and Moura, who influence the network through the publication of texts, as well as references in published texts, which can be constituted by (self)citations. This relationship shows that researchers tend to assume their own ideas and those of their peers, suggesting a predominance of internal links in which ideas and collaborations are concentrated within specific groups, which may limit openness to external collaborations and dialogue.

When we turn to Figure 4 of the analysis, we note that the citations are organised into two main groups of authors, represented by the red and green clusters. Thus, why do these studies focus on these authors? What does that

mean? In order to seek answers to our questions, we seek the meaning of the word “concentrate”. The Houaiss dictionary (2004) defines it as: converging at the same point; presenting itself in large quantity or intensity; gathering in a delimited space. Going further, in this last sense, to gather means “jointly,” “to cluster.”

We understand that, for research to focus on these authors, there must be convergence of ideas and practices in teacher education. These authors may relate in some way; that is, they are grouped academically. To deepen our understanding of what was shown in the network, we looked up these authors in the Lattes curriculum and found their areas of study.

João Pedro da Ponte, according to the *Ciência Vitae* curriculum⁴, holds a doctorate from the University of Georgia in the United States and is a professor emeritus at the Institute of Education of the University of Lisbon. He was a visiting professor at several universities, including in Brazil. Ponte works in mathematics education, researching aspects of the teaching of algebra, professional knowledge, teaching practice, professional development, and teacher education. Fiorentini et al. (2019) state that Ponte was a visiting professor at Unicamp, the university where researcher Dario Fiorentini works.

Dario Fiorentini is a researcher and retired professor at Unicamp. According to Lattes⁵, although retired, the author continues to conduct research and teaching activities, now as a volunteer. Fiorentini holds a PhD in education from Unicamp under the supervision of Ubiratan D’Ambrósio, one of the biggest names in mathematics education. Also, according to Lattes, the researcher investigates mathematics education, teacher education and professional development, and knowledge of learning and teaching in mathematics. Fiorentini has advised research projects and formative programs abroad, in addition to serving as a visiting professor at universities, including the University of Lisbon in Portugal, where researcher João Pedro da Ponte works.

According to Ferreira (2003), Dario Fiorentini played a fundamental role in the development and consolidation of the “education of teachers who teach mathematics” as a research theme in Brazil. The author also notes that, in

⁴ João Pedro da Ponte's curriculum was accessed through the link: <https://www.cienciavitae.pt/portal/6D1A-43D8-25B4>.

⁵ Dario Fiorentini's curriculum was accessed through the link: <http://lattes.cnpq.br/9244474518505985>.

her doctoral thesis, Fiorentini presents important aspects for understanding research and, together with her students and research group, developed studies that deepened and expanded this theme.

This aspect shows that, in the Brazilian context, Dario Fiorentini and his group are among the precursors of research on the education of teachers who teach mathematics. This influence remains to this day, since the author is among the most cited in the texts presented in SIPEM.

The fact that Fiorentini was a visiting professor in Lisbon, where Ponte works, and a visitor at Unicamp, where Fiorentini works, may have brought the authors closer. In addition, Fiorentini cites many of Ponte's works (Reis & Fiorentini, 2009; Maia et al., 2024); Fiorentini also carried out several interviews with Ponte (Fiorentini et al., 2019). According to the Lattes platform, Ponte and Fiorentini also organized, in 2005, the I Luso-Brazilian Seminar on Mathematical Investigations in the Curriculum and Teacher Education, co-authored a book chapter with other researchers, and served on doctoral panels together. These aspects show that Ponte and Fiorentini have theoretical connections and some degree of academic cooperation, especially in the education of teachers who teach mathematics.

Another author who stood out in our analysis is Adair Mendes Nacarato, PhD in education from Unicamp, advised by researcher Dario Fiorentini. According to the Lattes curriculum⁶, the author is a leader of research groups and works on themes in mathematics education, such as teacher education, pedagogical practice, and (auto)biographical narratives. Considering that Adair Mendes Nacarato was advised by Dario Fiorentini, we observed that she continued the same line of research as her advisor, strengthening the theme of the education of teachers who teach mathematics in the country and serving as one of the main references.

Márcia Cristina de Costa Trindade Cyrino, another author strongly cited in the works on the education of teachers who teach mathematics, holds a PhD in education from the University of São Paulo and was also advised by Ubiratan D'Ambrósio. According to the Lattes curriculum⁷, the author completed postdoctoral research at the Faculty of Sciences of the University of

⁶ Adair Mendes Nacarato's curriculum was accessed through the link: <http://lattes.cnpq.br/4651130852101924>.

⁷ Márcia Cristina de Costa Trindade Cyrino's curriculum was accessed through the link: <http://lattes.cnpq.br/0809818122632169>.

Lisbon in the area of teacher education and at the Institute of Education of the University of Lisbon. Cyrino currently works and coordinates a study and research group focused on the education of teachers who teach mathematics.

Cyrino and Fiorentini were guided by Ubiratan D'Ambrósio, who offered theoretical approximations and perspectives on mathematics education and teacher education. In addition, the authors share academic links, such as e-books developed in partnerships (Fiorentini et al., 2016; Paula & Cyrino, 2020). They also participate jointly in master's and doctoral examination boards and in round tables. In this same sense of board/orientation, Cyrino and Nacarato also have academic connections.

We understand that, as far as research is concerned, Ponte, Fiorentini, Nacarato, and Cyrino share a common core in the education of teachers of mathematics, even though they have different understandings and research fronts. Their theories dialogue with each other, and it may be that the work of one complements or even inspires the other. Thus, this first red cluster reveals that these authors are often mobilised together to support studies on practice and education, which explains the strong co-citation network shown in Figure 4.

In the cluster represented in green, the authors Moretti, Moura, Leontiev, and Vygotsky stand out. According to Lattes⁸, Manoel Oriosvaldo de Moura holds a doctorate from the University of São Paulo and works in the field of mathematics education with a focus on mathematics teaching methodology, teacher education, and activity theory. The author also leads a research group on pedagogical activity.

Regarding the author Vanessa Dias Moretti, she holds a doctorate from the University of São Paulo and was advised by Moura. According to her Lattes curriculum⁹, she is also a researcher in the research and studies group led by Moura, so both have a strong academic relationship. Moretti develops research in mathematics education, focusing on the TTMs' initial and continuing education, teaching learning, teaching activity, and historical-cultural theory, and his ideas and works tend to follow the same theoretical line as Moura's.

⁸ Manoel Oriosvaldo de Moura's curriculum was accessed through the link: <http://lattes.cnpq.br/3536854228318246>.

⁹ Vanessa Dias Moretti's curriculum was accessed through the link: <http://lattes.cnpq.br/0324707549177305>.

Vygotsky and Leontiev, whose names are also in the centre of Figure 4, are researchers in historical-cultural psychology. According to Moraes and Moura (2009), Vygotsky and Leontiev understand education as a universal means of human development. Moraes and Moura (2009) also affirm that Leontiev focused his studies on understanding human activity, drawing on Vygotsky's assumptions. Thus, it is possible to observe the relationship between Vygotsky and Leontiev and to understand how the researchers Moura and Moretti, guided by historical-cultural theory, articulate these studies with teacher education.

We understand that, although the authors appear in different clusters, they relate through authors who articulate historical-cultural theory with studies on the education of teachers who teach mathematics. While the green cluster brings together theoretical foundations, the red cluster gathers researchers from teacher education. The connection between them occurs mainly through authors such as Moura and Moretti, who mobilise the assumptions of historical-cultural theory to analyse and support research on teaching and teacher education, as well as through the national curriculum documents represented by Brasil.

Jurisdiction Brasil, considered here as the author for research purposes, was constituted by all national curriculum documents that are cited in the analysed texts, such as the Law of Guidelines and Bases of National Education (Lei de Diretrizes e Bases da Educação Nacional—LDB), the National Curriculum Parameters (Parâmetros Curriculares Nacionais—PCN), the National Curriculum Guidelines (Diretrizes Curriculares Nacionais—DCN), the National Common Curriculum Base (Base Nacional Comum Curricular—BNCC), in addition to other resolutions and laws that guide education and teacher education in the national context. Through Figure 4, it is possible to identify a predominance of citations of curriculum documents in the proceedings of the IX SIPEM, which may occur in the sense that researchers seek to problematise the legislation and also because the theme of education of teachers who teach mathematics in Brazil is strongly influenced and discussed by national educational policies and curriculum reforms, since the publication of curriculum documents such as LDB 9394/96, the National Curriculum Parameters (PCN) and the National Curriculum Guidelines (DCN) (Santana et al., 2024).

The discussions in this context seek to understand and define the structure and organisation of courses that address the education of teachers who teach mathematics (Lopes et al., 2023), as well as the organisation of

mathematics teaching, taking the normative dimension as a reference (Santana et al., 2024). Therefore, researchers, in the context of the education of teachers who teach mathematics, often resort to these discussions and the guiding documents that support them when developing their research and teaching practices, seeking to problematise the legislation, as well as to align their reflections and proposals with national educational policies.

SOME CONSIDERATIONS

The analysis and interpretation of the phenomenon under investigation revealed that the education of teachers who teach mathematics is a theme encompassing specific sub-themes, such as the professional development of these teachers and their mathematical knowledge, among others. These specific and diverse sub-themes may show dispersion among researchers, since each researcher or group of researchers directs their research according to their interests.

However, although the investigations are directed to different sub-themes, at some point, they tend to draw on theoretical references considered influential or “classic” in the context of the education of teachers who teach mathematics, whether they are national theoretical references, such as Fiorentini, Nacarato, and Cyrino or international ones, such as Ponte.

In this context, the research also revealed that the education of teachers who teach mathematics, as it is a broad topic, also involves other fields of knowledge, such as education, psychology, and philosophy, by using the ideas of authors such as Freire, Vygotsky, and Leontiev, who are not researchers in the field of mathematics education, but present ideas that underlie the practices and conceptions of teaching and learning in this field.

Finally, the analysis and interpretation of the networks of citations and co-authorship emerging from the proceedings of the IX SIPEM enabled mapping and explaining relationships in the context of the education of teachers who teach mathematics. Although the network is broad and offers potential for further investigation, the results allow us to identify the consolidation of this theme across the national and international scenarios, as well as the advancement of research as sub-themes of study expand and diversify.

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AUTHORSHIP CONTRIBUTION STATEMENT

NFS, TFC, and TEK conceived the idea and the theory presented. NFS and TFC performed data production and analysis. NFS, TFC, TEK, RSC, and RCB participated in the discussion and interpretation of the data. All authors actively participated in the preparation, reading, review, and approval of the final version of the work.

DATA AVAILABILITY STATEMENT

The data supporting the results of this research will be made available by the corresponding authors, NFS and TFC, upon reasonable request.

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