

Research in teaching chemistry¹ in Brazil between 2002 and 2017 from specialized journals^{2*}

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Abstract

This article aimed to map some parameters of the Research in Chemistry Teaching in Brazil from the analysis of the publications of six specialized journals. For this purpose, scientometric indicators of production and documentary analysis of 333 articles identified between 2002 and 2017 were used. The results show an increase in the number of publications on chemistry teaching, especially since 2009, being the third most representative area within the natural sciences, with a projection of equality between physics and biology. Publications show a regional predominance from the Southeast and South and from the states of São Paulo, Rio Grande do Sul and Minas Gerais, with a growth trend in the Northeast region. Investigations with students (higher and secondary education) and basic education teachers are the most recurrent. With respect to the thematic nature, questions about teaching and learning from the perspective of the teacher's theoretical and practical knowledge, pedagogical actions in the classroom, development of concepts and thinking, already consolidated in the area, prevail. In general, these data are in line with international studies and a research agenda focused on empirical investigations and concentrated on issues of teaching and training of undergraduates and teaching practices and knowledge. The themes of diversity, technologies, and non-schooling spaces are still not very representative, and can be considered research gaps. Among the challenges of

* English version by Luanda Hepp Alves. The authors take full responsibility for the translation of the text, including titles of books/articles and the quotations originally published in Portuguese.

1- There is a debate among researchers that the term chemical education is more appropriate to describe the research area. However, we chose to follow the terminology chemistry and science teaching in line with area 46 of the Coordination for the Improvement of Higher Education Personnel (CAPES) created as science and mathematics teaching in 2000, later changed to "teaching" in 2011.

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the area are the greater participation of school institutions in knowledge production, the reduction of regional asymmetries, as well as international collaboration.

Keywords

Bibliographic research – Research in Chemistry teaching – Scientific articles.

Introduction

Research in Chemistry Teaching (PEQ) is an area that has grown significantly in the Brazilian context. Some studies have pointed out important milestones in its constitution over the years (CHASSOT, 1995; SCHNETZLER, 2002), many of them in line with the very emergence of the area of science teaching in Brazil, such as the role of scientific societies, science funding policies and the implementation of Postgraduate studies in the country (NARDI, 2007).

For the particular case of the PEQ, Schnetzler (2002) highlights six relevant milestones. The first of them was the creation of the chemistry teaching division of the Brazilian Chemical Society (SBQ) in 1988, whose embryo was born in the first annual meeting of the entity that took place in 1978, from a coordinated session that exceeded the allotted time. Another milestone was - and still is - the organization of specific events to bring together the studies developed. Still in the 1980s, the first meetings focused on the teaching of chemistry were held, which have lasted until today. The pioneer of these was the *Meeting of Debates on the Teaching of Chemistry* (EDEQ), held in 1980. In 1982, the first *National Meeting for the Teaching of Chemistry* (ENEQ) was held, a biannual event that became the country's main meeting on the subject.

Schnetzler (2002) also highlights the Education section of the annual SBQ meetings and the *Química Nova* journal. The increase in the presentation and publication of papers contributed to the dissemination of knowledge and culminated with the fourth major milestone, the search for funding and the creation of the first specific journal on the Teaching of Chemistry, the magazine *Química Nova na Escola*, in 1994. Finally, there is the formation of masters and doctors in the teaching of chemistry and the increase of publications in the area (SCHNETZLER, 2002). It is understood that other aspects have ensured not only the continuity, but a significant development of research. One of these new remarkable factors is the creation of the area of science and mathematics teaching of CAPES in the year 2000, accompanied by the exponential growth of Postgraduate programs (PPGs), responsible for numerically resizing the events and publications.

The significant increase in the critical mass of researchers resulted in what can be considered the most recent historical milestone: the founding of a specific scientific entity, the Brazilian Society of Chemistry Teaching (SBEnQ), whose discussions officially began in 2016 during the XVIII ENEQ in Florianópolis, materializing with the approval of its creation during the XIX ENEQ in Rio Branco/AC in the year 2018 (SBENQ, 2018).

Given the context, it is believed that a reading of the panorama of research can contribute to a better perception of this field. In this direction, this work aimed

to map some parameters of the Research in the Teaching of Chemistry in Brazil from specialized journals in science teaching, trying to answer the following questions: what is the representativeness of the research area in chemistry teaching in the investigated dissemination vehicles? What is the origin of the research in terms of institutions and geographic regions of the authors? What are the main themes and objects/subjects of research? What challenges are posed for the coming years?

Research on scientific production and the panorama of the area of chemistry teaching

There is a recurrence of studies that aim to survey information and scientific production in certain fields of knowledge. This type of research allows a diagnosis of emerging and recurrent issues, contributing to the improvement of research. In general, they are developed from the perspective of the state of the art, as well as from scientometrics.

State of the art research is bibliographic in nature and aims to map and discuss the academic production in a given field of knowledge, from which aspects that stood out and gaps in different times and places are analyzed (FERREIRA, 2002). According to Ferreira (2002), such studies are based on documentary analysis, usually carried out in two stages. The first stage identifies bibliographic data for the mapping of production in a delimited period, its places and areas. In the second moment, the aim is to go beyond the questions of when, where, and who produces the research, looking at questions that refer to the what and how of the work.

In turn, scientometrics is a branch of the sociology of science and can be understood as the quantitative study of scientific data, including publications (SILVA; HAYASHI; HAYASHI, 2011). Patra, Bhattacharya and Verma (2006) consider scientometrics as a measure of scientific communication. Such measures are applied, from specific indicators, for the description of the evolution of research over time, as well as for a panorama of the behavior of scientific production in a given area, thus substantiating analyses and conclusions (BUFREM; PRATES, 2005). Spinak (1998) points out two major groups of indicators in scientometric research: production and citation. The production indicators measure the quantity and impact of publications, using, for example, number of articles by regions and institution, growth rate of publications, authors' productivity, among others. Citation indicators basically measure the quantity and impact among scientific publications, using citation and co-citation analysis, impact index, popularity factor, etc.

Regarding the studies about the panorama of the science teaching area as a whole, Megid Neto (2007) has historically documented the area between 1972 and 2003. The author registered the predominance of physics teaching, followed by biology and chemistry, which started to grow after 1995. He also points out the predominance of Universidade de São Paulo (USP), the Southeast and South regions, and research on the teaching and learning process. Delizoicov, Slongo and Lorenzetti (2013), based on the analysis of the first five editions of the National Meeting for Research in Science Education (ENPEC), present results similar to those of Megid Neto (2007) in terms of region and trends among the areas of physics, biology and chemistry. Similarly, Razera (2016) evaluated the theme teacher education based on scientometrics, also signaling the field of physics teaching as the most recurrent, but with good participation of biology and chemistry teaching.

With the growth of Research in Chemistry Teaching it is also possible to verify investigations that evaluated the scientific production in the area. Francisco and Queiroz (2008) examined the abstracts presented in the chemical education section of the Annual Meeting of the SBQ from 1999 to 2006. The authors highlight the significant growth in the number of papers, basic education as the main locus, and the diversity of themes. Matiello and Bretones (2010) mapped theses and dissertations defended from 1973 to 2008. The Southeast region was responsible for the majority of productions, with USP being the holder of the largest production and secondary education being the most recurrent level of schooling. Francisco, Alexandrino and Queiroz (2015) investigated theses and dissertations on the subject of chemistry teaching defended in PPGs of education from 2000 to 2008, corroborating the trend data and geographical region of the productions, showing the Southeast and South regions in the lead, as well as USP in terms of institutions. Both studies show a growth trend starting in 2008. Silva and Queiroz (2016) and Fonseca and Santos (2016) analyzed dissertations and theses on teacher education, pointing out similar trends in terms of distribution and growth.

In relation to the research that stopped at journals, in general they are addressed to specific themes and some reaffirm the representativeness of chemistry teaching. Albuquerque (2018), for example, focusing on the Science, Technology and Society (STS) theme in national journals, revealed the presence of three authors from chemistry education among the twelve most cited papers. The data also showed a large predominance of authors from the Southeast region (64 percent) and South (26 percent). Also on CTS, Abreu, Fernandes and Martins (2013), examining journals and events, listed chemistry teaching researchers among the most cited - two among the three most cited Brazilians. The authors also point out a certain distribution of papers on the teaching of biology, physics and chemistry, as well as the recurrence of teachers as investigated subjects.

The growth of PEQ is described by Mortimer *et al.* (2015) based on *Química Nova na Escola*, the first specific Brazilian journal on chemistry teaching. Despite not exclusively publishing research, accepting articles of experience reports, analysis of concepts, and experiment proposals, the data mark a growth of almost 400 percent of research articles in the period 2005-2014 compared to 1995-2004, with an increase in the participation of Postgraduate students.

Considering that the analysis of the panorama of production in chemistry teaching is little addressed from the point of view of specialized journals, the documentary (or documental) study of content, combined with scientometric indicators, can bring information that still remains latent about the field. While the proposed survey is not intended to be exhaustive, the analysis from this point of view enables a broader understanding of the area, being representative so that other horizons and challenges can be unveiled.

Methodology

This study fits into a quantitative and qualitative perspective that relies on scientometric techniques from production indicators (SPINAK, 1998) and documentary analysis of the selected texts (LÜDKE; ANDRÉ, 2017). The first step was the choice of

document types. Periodicals were chosen, given the lack of a longitudinal approach with articles from this field as a whole.

The choice of journals for analysis was based on three interconnected criteria. First, the scope, which should be directed to science education. Then, the maturity and acceptance by the research community, whose references were the time of existence - uninterrupted publication since 2002, when the first PPGs of this field of science teaching of CAPES were initiated - and the classification in strata A in the Qualis in force at the time of the research - 2013/2016 - for the area of Teaching. Six journals that met all the criteria were then selected: *Ciência & Educação* (A1); *Ensaio: Pesquisa em Educação em Ciências* (A1); *Investigations in Science Teaching* (A2); *Revista Brasileira de Pesquisa em Educação em Ciências* (A2); *Acta Scientiae*: Revista de Ensino de Ciências e Matemática (A2), *Revista Electrónica de Enseñanza de las Ciencias* (A2), hereafter referred to as *C&E*, *Ensaio*, *IENCI*, *RBPEC*, *Acta* and *REEC*, respectively. *REEC* is the only one not published in Brazil, but it shows a strong representation of the Brazilian science teaching community, responsible for half of the articles published in the evaluated period.

After the selection of the periodicals, we proceeded to map the articles on the specific sites of each vehicle. The search for publications was based on the descriptors “chemic”, “physic” and “bio” in the title, abstract or keyword. The choice of the major areas of the natural sciences - physics, biology, and chemistry - was based on the study of the representativeness of PEQ compared to the others. The period covered was from 2002 to 2017, as it is significant in the historical path of area 46 of CAPES. The area was created in 2000, the year in which the first master’s course was approved, and its operation started in 2001. In 2002, the area approved its first doctorate course (MOREIRA, 2002). Thus, the historical series allows the unveiling of characteristics and trends of publications concomitantly with the influences arising from the growth of Postgraduate studies.

After the screening, all articles had their abstracts read for a first verification of adequacy, being discarded only one for not fitting the teaching of chemistry. After mapping the general *corpus*, the representativeness of the area of PEQ was evaluated through absolute numbers and percentages. Next, a quantitative analysis of the texts in the area of chemistry teaching was carried out based on analytical scientometric indicators of production: i) distribution by journal and chronological publications; and ii) authors - geographical origin, institutional and cooperation.

We then proceeded to the documentary analysis of the selected articles. For this, a full reading was carried out in order to categorize the audience and/or objects of study and the thematic focus of the investigations. Such indicators are commonly used in national and international works about the characterization of the science teaching area (FRANCISCO; ALEXANDRINO; QUEIROZ, 2015; MEGID NETO, 2007; TEO; GOH; YEO, 2014; TSAI; WEN, 2005). Especially for the thematic focus indicator, the analysis was performed independently by two researchers. The degree of agreement was 84.5 percent. Divergent cases were discussed with a third researcher until consensus was reached.

After the data were classified, they were quantified and grouped in order to produce new interpretations. Finally, an interpretative analysis was performed based on the generated data, presented with the help of descriptive statistics. The discussion of the

results took into account other works about the panorama of research in science and chemistry teaching, as well as the scenario of the area of science teaching in Brazil, based especially on the area data from CAPES.

Results and discussion

From the collection of the selected journals, a total of 2,761 articles published between 2002 and 2017 were identified. Of these, 333 (12.1 percent) contemplate Research in Chemistry Teaching. The results are presented according to the general analytical indicators.

Distribution by journal and chronological distribution of publications

Table 1 presents the absolute number and percentage of publications in each journal in general terms and in the three major fields of the natural sciences. *Ciência & Educação* presented the largest total number of articles. It is the oldest journal – created in 1994 – and the one with the most contributions from foreign authors, also publishing about mathematics education.

Table 1 – Number and representativeness of articles published by area - chemistry, physics and biology - in each journal analyzed

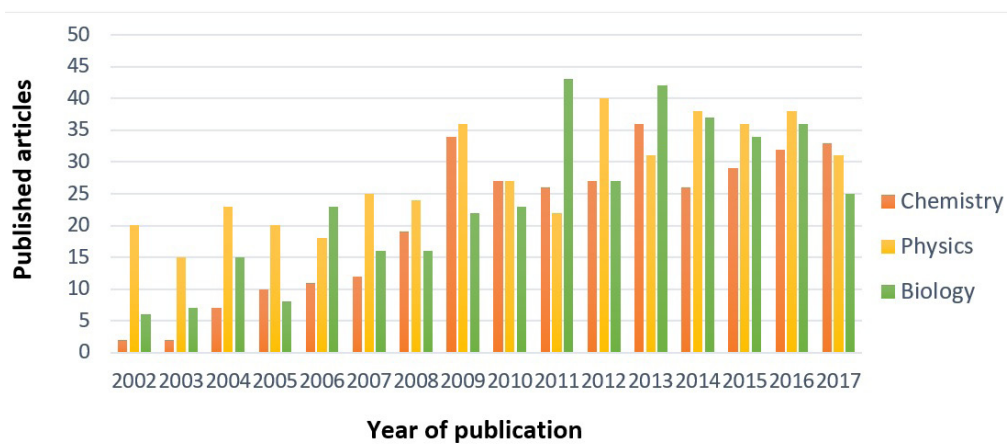
Periodical	Chemistry	Biology	Physics	Total
	Number of articles (Representativeness)	Number of articles (Representativeness)	Number of articles (Representativeness)	Number of articles (Representativeness)
C&E	66 (9,28%)	96 (13,5%)	106 (14,9%)	711 (25,8%)
IENCI	47 (12,4%)	76 (20,0%)	94 (24,7%)	380 (13,8%)
RBPEC	65 (16,4%)	61 (15,4%)	80 (20,2%)	396 (14,3%)
Ensaio	49 (12,8%)	64 (16,8%)	75 (19,6%)	382 (13,8%)
Acta	38 (8,86%)	30 (6,99%)	33 (7,69%)	429 (15,5%)
REEC	68 (14,7%)	53 (11,4%)	56 (12,1%)	463 (16,8%)
Total	333 (12,1%)	355 (13,8%)	444 (16,1%)	2761 (100%)

Source: Research data.

In terms of the three major areas, there is a small internal oscillation among the journals, without changes in the panorama of greater representation of physics, with the exception of *REEC*, in which chemistry was more representative, but in values close to the others. This suggests some stability in the consolidation of these vehicles for publications in science education. The lowest representativeness of all areas is concentrated more markedly in *Acta Scientiae* and, to a lesser extent, in *C&E*. This fact is due to the publication of research in mathematics education in these journals, which does not occur in the others.

In general, it is possible to state that the area of chemistry teaching is considerable in all the selected vehicles, presenting a slight inferiority in the general panorama in comparison with the other major areas. These results are in agreement with other surveys. Megid Neto (2007), based on 1,071 theses and dissertations between 1973 and 2003, pointed out the field of chemistry as the third most representative (11 percent), with values slightly lower than those of biology (14 percent). Physics, on the other hand, represented a large majority, with 38 percent of the total. The author already inferred the equalization between the areas, a trend pointed out by the data from the journals. Delizoicov, Slongo and Lorenzetti (2013), mapping the papers of the first five ENPECs, an important event for the teaching of natural sciences, showed similar data, in which physics was the most representative (27 percent), followed by biology (21 percent) and chemistry (15 percent), also signaling the growth of the last two. Razera (2016), in a scientometric study in the periodical *Ciência & Educação* from 1998 to 2014 on the subject of teacher education, indicated the prevalence of physics already in values closer to chemistry and biology. Based on the examination of four international journals of science teaching between 2003 and 2014 with high impact factor in the area, Teo, Goh, and Yeo (2014) reported a slightly lower representation for the teaching of chemistry, 7.7 percent, but with a similar number of articles in the same period compared to the present study – 206 versus 209. These data also express that, in quantitative terms, the Brazilian community is strong.

The analysis in temporal terms (Figure 1) allows us to confirm the growth of the areas of biology and chemistry in the number of publications, with some stabilization in the last four-year period. In the first four-year period analyzed, the area of physics was predominant, with twice as many articles compared to biology and almost four times as many compared to chemistry – 78 articles on physics teaching versus 36 articles on biology teaching and 21 on chemistry teaching. Over the years there has been a tendency to balance between these three major areas. The last four-year period searched shows the approximation of the areas of physics and biology – 143 and 132 articles published, respectively – while chemistry is at a slightly lower level – 120 articles. These data corroborate the trend towards a better balance between the three disciplinary areas in the future.



Source: Research data.

Figure 1 - Distribution of research articles on the teaching of chemistry, physics and biology over the period investigated

The growth of publications on the teaching of chemistry is more evident from 2009 onwards. After this year, the number of publications always remained above 25 articles/year, exceeding thirty articles in the last two years of the analysis. Mortimer *et al.* (2015), in an analysis of PEQ articles published in *Química Nova na Escola*, describe a growth of almost four times from the first - from 1995 to 2004 - to the second decade of existence - 2005 to 2014 -, indicating the strong participation of Postgraduate students in these publications. Silva and Queiroz (2016), in an analysis of theses and dissertations on teacher education in chemistry, point out growth from 2007. Kundlatsch and Cortela (2018), investigating the theme of comics in the teaching of chemistry through scientometric techniques, verified growth from 2009. In that same year, there was an increase in theses and dissertations on experimentation in chemistry teaching (SOUZA; CABRAL; QUEIROZ, 2019). Thus, it can be inferred that PEQ, in general, has a turning point for increased representativeness at the end of the first decade of the 2000s.

The rise in publications in journals in historical terms appears closely related to the development of the area of education. According to data from the area report (CAPES, 2017), there were only seven programs in 2002, and in 2012 there were already eighty, a number that jumped to 136 in 2016 - a growth of 70%. Another relevant data between the years 2013 and 2016 was the number of degrees: 908 PhDs and 5,033 masters in teaching (CAPES, 2017). These figures represent 67.7 percent of the PhDs and 48.5 percent of the master's degrees in the entire history of the area, excluding, in these cases, masters and PhDs held in programs in the area of education and those from specific PPGs, which also have representativeness. It is also worth noting that researchers in chemistry teaching - or science teaching - are not trained exclusively in programs in the area of education. Programs in the areas of education and chemistry have a significant contribution (SILVA; QUEIROZ, 2017).

However, the number of articles between 2014 and 2017 in the journals did not follow this growth trend. The six journals published 292 articles in 2014, 290 in 2015, 279 in 2016, and 247 in 2017. In the meantime, the number of articles published is not representative for the growth trend of research in the country, even though there are other dissemination vehicles not incorporated in the research. This point deserves analysis by researchers, editors, and reviewers of science education - and probably education - journals. The journals face difficulties in providing an outflow of publications due to the growth of the area, and a greater dialogue among the community is necessary to minimize possible impacts on scientific production. The six journals analyzed here are representative of a scenario in which communication of research is hampered.

Geographical, institutional and cooperation origin among authors

With respect to the participation of the geographic regions, we verify a not very equitable distribution (Figure 2). The representation shows the predominance of

the Southeast region, whose authors were present in almost half of the articles (165, corresponding to 49.5 percent) and the South region (31.2 percent). In sequence are the Northeast (20.4 percent), the Center-west (4.2 percent), and the North (4.8 percent). This trend of predominance of regions is commonly reported in other research (DELIZOICOV, SLOGO; LORENZETTI, 2013; FRANCISCO; ALEXANDRINO; QUEIROZ, 2015; MEGID NETO, 2007) and is explained by the regional asymmetry of Postgraduate courses and the presence of researchers as a whole.

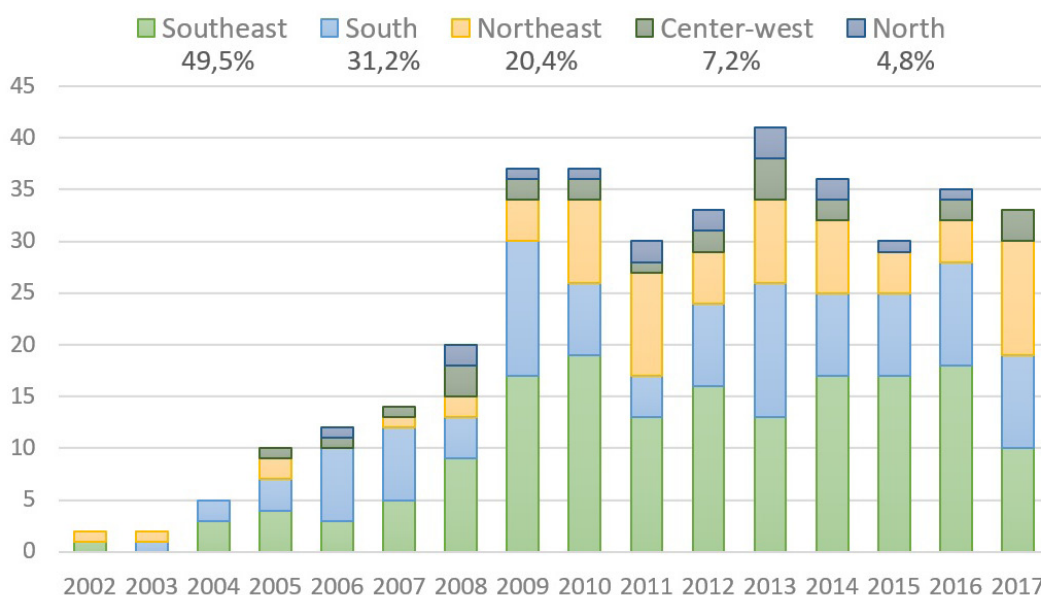


Figure 2 - Articles published by regions according to each year analyzed

Source: Research data.

In relative terms, the representativeness of the Southeast region grows during the analyzed period - 38 percent in the first four years and 51.7 percent in the last four years. As for the South, the second most representative region, there is no significant temporal variation. In the first four years, authors from the South region were present in 28.6 percent of the publications, a number almost identical to the last four years (29.2 percent) and to the total average (31.2 percent). In turn, the period between 2010 and 2017 revealed minor important changes from a trend standpoint.

There is a growth in the participation of the Northeast region, whose representativeness (24.1 percent) was close to that of the South region (28.4 percent), and was higher in some years. In 2017, for example, the Northeast region was the most representative among all, the only year in the entire historical series. It is worth noting the impact of this data on the overall survey, discussed earlier. The year 2017 was the first year in which PEQ showed

above physics and biology (Figure 1). This allows us to correlate the growth of the area in the country with the growth phase of the Northeast region.

Until 2007, the articles from the Northeast region originated mostly in Bahia and Pernambuco, from the respective Postgraduate programs in the area of education. However, the creation and consolidation of other programs, especially in the states of Rio Grande do Norte, Sergipe, Alagoas and the countryside of Bahia, whose publications started from 2010, caused a growth in the participation of the Northeast region. The publications arising from these states - twenty articles - represent 6.0 percent of the total and 29.4 percent of the Northeast production.

Between 2013 and 2016, enrollment at the doctoral level in teaching PPGs increased 114 percent in the Northeast, 65 percent in the South, and 13 percent in the Southeast region (CAPES, 2017). In the case of master's degrees, enrollments in the Northeast region rose by 237 percent, while in the South and Southeast regions this number was 29.8 and 49.4 percent, respectively. This trend is aligned with the greater university expansion in the Northeast compared to the other regions (ZAMBELLO, 2013), increasing the demand and need for vacancies in postgraduate courses which suggests a maintenance of further growth. Such hypothesis is also anchored in the recent approval of the doctoral course of the Rede Nordeste de Ensino (Renoen), which involves six states and more than sixty doctors - eleven of whom are researchers in chemistry teaching - from seven different Northeastern institutions (CAPES, 2020). It is also worth mentioning the approval of the doctoral courses in science education at the Universidade Estadual do Sudoeste da Bahia (UESB) and the Universidade Estadual da Paraíba (UEPB). Such courses will have an even greater impact on the number of enrollments and graduates, which will probably reverberate in the productions. Therefore, a greater representation of the Northeast region is projected on the national scene in the 2020s, perhaps becoming the second most representative in terms of scientific production and decreasing the percentage contribution of the Southeast region.

Also, between 2010 and 2017 the contributions of the North and the Center-west regions were close in numbers - twelve and sixteen articles, respectively - being present in all years except 2015 for the Center-west region and 2017 for the North region. The production of the Center-west region originates almost exclusively from PPGs in science education from Goiás and the Federal District. The publications from the North region in the period do not derive specifically from links with Postgraduate studies, but from the activities of two federal universities, the one of Rondônia (UNIR) and Tocantins (UFT), which participated in ten of the sixteen productions - five each - representing 62.5 percent. The UFT studies are authored by two researchers who have already changed institutions, and those from Rondônia come from a single research group. The Rede Amazônica em Educação em Ciências may play a fundamental role in the region's growth. Considering that the first doctoral classes began completion as of 2014, it is not yet possible to identify this impact. Thus, a growth is expected for the North region starting in 2020.

According to Table 2, cooperation between regions can be evaluated as significant - 12.6 percent of publications. Inter-institutional and regional cooperation are positive, as they allow networks and research programs to be created and strengthened. The high

representativeness of the Southeast also stems from institutional cooperation, since the region appears in 31 of the 42 cases, and most partnerships were made with authors from the Northeast (42.8 percent), especially from researchers who did their doctoral studies in Higher Education Institutions (HEIs) based in the Southeast region. The increase of courses offered in the Northeast region will probably have an impact on these cooperations, contributing to decrease the representativeness of the Southeast one. However, cooperation between authors from different regions is still an important factor in reducing regional asymmetries and strengthening the field of research.

Table 2 - Partner regions in the publications

Partner regions	Number of publications
Northeast and Southeast	18
Southeast and South	7
Southeast and Center-west	4
Northeast and North	3
North and Center-west	3
South and Northeast	3
South and Center-west	2
North and Southeast	2
TOTAL	42

Source: Research data.

Only five articles were identified in conjunction with foreign authors from Portugal - two cases -, Spain, Venezuela/Spain and Switzerland, suggesting low cooperation with the international community. The search for cooperation or the attraction of authors for publication in these journals is a way to strengthen the national and international research programs, as well as the dissemination vehicles themselves with their greater internationalization. It is certain that numerically the Brazilian community of PEQ is superior to that of Iberoamerican countries and can take on such a challenge. There is, therefore, a gap in this type of cooperation that can contribute to the spreading and circulation of knowledge.

In terms of federative units, 23 participate in the publications. No publications were identified with authors from Amazonas, Amapá, Roraima, and Maranhão. As expected, the states of São Paulo (30.9 percent), Rio Grande do Sul (17.4 percent), and Minas Gerais (15.0 percent) are the most representative. Paraná (9.0 percent), Pernambuco (7.5 percent), Santa Catarina (6.6 percent), Bahia (5.7 percent) and Rio de Janeiro (5.4 percent) also have relevant contributions. All the others have less than 4 percent representation. One point to note is about Rio Grande do Sul, which has 22 of the 58 (38 percent) articles published in

Acta - 58 percent of the articles listed for the journal -, showing a high regional endogeneity, which contributed to the second largest representation.

The universities of São Paulo (USP) with 20.1 percent, Universidade Federal de Minas Gerais (UFMG) with 9.31 percent, and Universidade Federal do Rio Grande do Sul (UFRGS) with 8.71 percent are the institutions with the largest representation in the publications. Also significant are the productions of Universidade Federal Rural de Pernambuco (UFRPE), with 6.0 percent, Universidade Federal de Santa Catarina (UFSC), with 5.7 percent, and Universidade Estadual Paulista (Unesp) and Universidade Federal de São Carlos (UFSCar), respectively with 5.4 and 5.1 percent. The others were present in less than 5 percent of the productions. Other studies have shown the relevance of USP and UFMG in the Research in the Teaching of Chemistry, as well as the relevant contributions of the others, with alternations of positions or emergence of other HEIs in the same range, depending on the objects of investigation (FRANCISCO; ALEXANDRINO; QUEIROZ, 2015; SILVA; QUEIROZ, 2017).

The data show precisely the influence of graduate programs in inducing publications. The most representative institutions and respective states are those whose PPGs, especially in science education, were the pioneers. A differentiating factor is the case of UFMG, whose contributions derive exclusively from the PPG in Education. In the case of USP, it is worth pointing out the contribution of different academic units, the College of Education, as well as the Chemical Institutes in São Paulo and São Carlos cities, favoring the high representativeness. The results once again corroborate the alignment between the growth of graduate studies and production in chemistry teaching.

Still in relation to institutions, the data show that the publications of PEQ have been an activity carried out predominantly in public university institutions (94 percent), as already pointed out by other studies (DELIZOICOV; SLOGO; LORENZETTI, 2013; MEGID NETO, 2007). Among private HEIs, the Universidade Luterana do Brasil (Ulbra) and the Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS) were the most prominent, respectively with authors in 3.6 percent (12) and 2.1 percent (7) of the articles. Despite the large participation of basic education teachers as research subjects, as we will see later, the expressiveness of these subjects as authors is still low, with nineteen articles (5.7 percent), revealing the fragile relationship between schools and universities as effective partners in the authorship of educational research. These data present agreement with the survey by Mortimer *et al.* (2015). However, basic education teachers presented a greater participation in *Química Nova na Escola*, being authors of 21 articles (12.1 percent) from 2005 to 2014. These data suggest the greater penetration of this journal in schools and the need for university researchers to lead a movement towards closer links with schools.

Audience or objects of study

The audience or focus objects of the research are directly associated with the research objectives and its thematic focus. In most of the articles identified, the subjects or objects were made explicit. In other articles there was confusion in the delimitation of the object.

Some articles presented more than one type of subject, such as teachers and students. The distribution is presented in Table 3.

Table 3 - Investigated objects that appeared in the analyzed articles

Research focus subjects or objects	Total	Representativeness (%)
Undergraduate Students	82	24,6
Basic Education Teachers	81	24,3
High School Students	56	16,8
Articles, dissertations and theses	31	9,3
Textbooks	31	9,3
Higher Education Teachers	14	4,2
Elementary School Students	12	3,6
Graduate Students	5	1,5
Students of Education for Adult and Young People (EJA)	2	0,6
Others	22	6,6

Source: Research data.

In the general context, students are the most representative participants. When all levels of education are added, the value is close to half of the total number of articles, expressing that this audience has been the center of research in Chemistry teaching, pointing to a research agenda with an applied character, as already recorded by Delizoicov, Slongo and Lorenzetti (2013) for the ENPEC. However, students of Elementary Education (FE), especially in the early grades, post-graduate (PG) and Education for Adult and Young People (EJA) had little emphasis (Table 3). Other investigations have already identified similar occurrences (BEJARANO; CARVALHO, 2000; FRANCISCO; ALEXANDRINO; QUEIROZ, 2015), often without the presence of EJA or PG. In all these levels of education there is a vast field of research to be explored that can bring new perspectives.

Articles that addressed undergraduate students are the most present (24.6 percent). The strong interest is related to the context of initial teacher education, which takes place at the undergraduate level, with the pointing of challenges and paths. Silva and Queiroz (2016), investigating the theses and dissertations produced for chemistry teacher education, pointed out that 54.6 percent were devoted to higher education. Both research on aspects of pedagogical training and conceptual learning with a focus on undergraduates can contribute to better professional performance. The data suggest that there is a significant body of knowledge produced, but that it needs to reverberate more effectively in the initial and continuing education of teachers. Together with the research that reports on continuing education experiences, this field seems to have reached a stage of robustness

whose future steps need support from public policies and greater circulation of this knowledge among the different instances responsible for training teachers, including the need to improve the training of educators.

Basic education teachers were the second group of subjects that most participated in research (24.3 percent). Many involved continuing education, which can be considered positive as far as it has a direct impact on teaching performance. The data are in line with other state of the art surveys that indicate the recurrent participation of teachers in research on science teaching in Brazil (FONSECA; SANTOS, 2016; FRANCISCO; ALEXANDRINO; QUEIROZ, 2015).

Although teachers participate as researchers, few effectively participate as collaborators. The number of authors who are basic education teachers is low and leads to reflection on how the formative process can be effectively impacted through research. While many studies focus on teachers as actors in continuing education, many others that have the teacher at the center of the analysis are about profile diagnosis, conditions, conceptions and professional practices, or even teacher knowledge. These studies of teacher characteristics are quite recurrent (FRANCISCO; ALEXANDRINO; QUEIROZ, 2015; MEGID NETO, 2007) and make little progress in solving or minimizing aspects linked to the formative process if they do not integrate the teachers. It is certain that research will not solve the problems of teaching, because there are other constraints. At the same time, efforts should be made to involve teachers more effectively in educational research that contributes to the educational process, displacing the *locus* from the academy as the privileged place to do research.

A similar thought can be directed to the studies focusing on higher education teachers, which present a relatively low number compared to basic education, with fourteen articles (4.2 percent). It is worth considering that these are the ones responsible for the training of new teachers and that they play a preponderant role, since many choices that undergraduates make can be a reflection of the higher education course. In surveys conducted on theses and dissertations whose focus was the training of chemistry teachers (SILVA; QUEIROZ, 2016, 2017), only one paper was identified with the purpose of discussing the training of undergraduate teachers. André *et al.* (1999), in turn, investigating teacher education in Brazil, detected two articles on teacher education for the upper level in a universe of 115 publications in journals between 1990 and 1997. The authors point to an almost total silence in relation to teacher training for higher education. Thus, research on higher education, especially on teacher training, is a theme to be further elucidated.

Research with high school students also stood out, with a total of 56 (16.8 percent). The studies by Megid Neto (2007) indicate that high school started to prevail in science teaching from the 1980s on. The expressive participation is explained in the context of teaching and learning chemistry, with applied research in real situations, given that, as a school subject, it is specific to this level of education.

Articles, dissertations and theses appeared in 9.3 percent of the cases (31). There are two strands to these publications. In the first (9), the articles were used as a source for an analytical essay on a theme or scientists. The second strand is characterized by literature reviews using articles (19) or theses and dissertations (3) as a source.

The analysis of textbooks also accounted for 9.3 percent - 31 articles - more than half of which were for high school (21), followed by books for elementary and higher education with five articles. The analysis of concepts prevails, but the themes are varied, including analogies, images and history of science. Such representativeness is close to the teaching resources category presented by Francisco, Alexandrino and Queiroz (2015), which figured around 11 percent. While it represents a considerable portion, there are many topics to be explored about textbooks at various levels of education, considering its strong penetration in the teacher's work. Research on textbooks can involve teachers in the analysis and discussion, contributing to the educational process.

The other category - 22 articles - comprises studies with specific objects or participants. Research on the National High School Exam (ENEM), the analysis of curriculum documents - National Curriculum Parameters, Curriculum Guidelines, Course Pedagogical Projects -, virtual communities, traditional communities' knowledge, university selection processes, literature books, science labs, among others.

Thematic focuses of the investigations

For this analysis we used, with some adaptations, the work of Tsai and Wen (2005), which proposes nine categories of thematic focus. The number of articles for each focus is shown in Table 4. It is worth noting that in 43 cases the same article was classified in more than one relevant focus.

Table 4 - Frequency and percentage of thematic focuses in the analyzed publications

Thematic Focus	Occurrences
Teaching	111 (33,3%)
Learning and its characteristics (development of concepts and thinking)	89 (26,7%)
Learning and assessment	47 (14,1%)
Teacher training	42 (12,6%)
Public policies, curriculum, and evaluation	29 (8,71%)
History and nature of science	25 (7,51%)
Cultural, social, and gender issues	15 (4,5%)
Educational technology	12 (3,6%)
Learning in non-school spaces	06 (1,8%)

Source: Research data.

Teaching was the most representative theme (Table 4), accounting for 1/3 of the research. These are studies from the perspective of knowledge, practices and materials (especially books) that present reflections with direct impact on the teaching process. This

was the main adaptation of the thematic focus of Tsai and Wen (2005), since there was no category for the analysis of teaching materials, especially books, originally.

In general, research has focused on the teacher's theoretical and practical knowledge, pedagogical actions and characteristics. Studies involving teacher characteristics are recurrent in the area of Brazilian science teaching, presenting similar representativeness according to other authors (FRANCISCO; ALEXANDRINO; QUEIROZ, 2015; MEGID NETO, 2007). There was a prevalence of articles (56) that contemplated the analysis of teachers' knowledge - chemical, pedagogical and nature of science - and of teachers' conceptions and social representations. The analysis of didactic and pedagogical materials - especially books - and their respective influences on teaching and teachers' work was the second most investigated sub-focus - with 27 articles. The analysis of books was diversified, including specific concepts, representations and images, analogies, and experiments. The didactic and pedagogical strategies used in the classroom were the third most investigated sub-focus (16). Other factors that interfere with teaching appeared in a smaller proportion, such as literature review on the teaching of specific concepts - with twelve articles.

There was a concentration on pedagogical issues in teaching practice. These approaches fit into the categories of teacher identity/professionalization and pedagogical practice used by André *et al.* (1999). The authors point out that such content accounts for about 50 percent of the research on teacher education in Brazil. Fonseca and Santos (2016), in a survey of articles on teacher training and work in the area of chemistry (2002-2015), found that the predominant discussions focused on policies, curriculum documents, and teaching proposals. A mindful look at these results is necessary, since they centralize the knowledge and practices of teachers in the educational process. At the same time that they point out the need to look at the teacher as an essential actor, they also hide important issues, which are the interferences in the process that go beyond the teacher, among them the very limitations of the initial training courses, the working conditions and the continuing education that reverberate in the knowledge and pedagogical practices.

The learning process and its characteristics focus, the second most identified (Table 4), includes articles that analyze the process of formation and development of concepts and thought. Investigations of this nature have been proving to be central to research on science and chemistry teaching since the beginning (FRANCISCO; ALEXANDRINO; QUEIROZ, 2015; MEGID NETO, 2007; TEO, GOH; YEO, 2014). Cachapuz *et al.* (2008), in a survey of international journals from 1993 to 2002, also indicate the strong presence of studies on learning. Language prevailed as the main sub-focus (38), with themes related to reading, discourse interactions, discourse analysis, writing, and representations. There was a marked growth in research on language, cognition, and learning, which became stronger after the 1990s with strong inspiration from the contributions on language and development of historical-critical psychology and semiotics. The role of teaching resources and methods in learning - experiments, modeling, analogies, argumentation, investigation, among others - was also very present (35). With less intensity, there were papers that emphasized the influence of environments - laboratory, non-school spaces, cooperative environment - on learning (16).

We identified 47 articles (14.1 percent) focusing on learning and assessment. These studies were characterized by the analysis of data collected at the beginning - study of previous knowledge - or at the end - evaluation - when it comes to a didactic intervention, not considering intermediate aspects of the process. Part (19) derives from the strong influence of the movement of preconceptions and conceptual change, still quite representative in the international community (TEO; GOH; YEO, 2014; TSAI; WEN, 2005). On the other hand, the majority - 28 articles - assess the impact of didactic proposals on the understanding of scientific knowledge, employing, for this purpose, various methods that evaluate students at the end of the process.

Teacher training was the fifth most representative theme, with 42 articles (12.6 percent), with a predominance of continuing education (21). The results are in agreement with other analyses (FRANCISCO; ALEXANDRINO; QUEIROZ, 2015; MEGID NETO, 2007; TEO; GOH; YEO, 2014). In this thematic focus, the publications were directed to a greater extent to experiences of teacher professional development in basic education, which is significant. Research includes production and analysis of teaching materials by teachers, courses on specific topics, and creation of teaching proposals. Many of these papers were also framed in more than one thematic focus, since the theme of the formative experiences was diverse, including technologies, nature of science, book analysis, and others. The other productions were dispersed, distributed among experiences and practices in initial training, as well as more theoretical investigations on policies, curriculum and evasion in training courses, the state of the art on teacher training, the construction of teacher identity, profile and models of teaching.

The theme public policies and curriculum gathered 29 articles (8.7 percent). Most of them (20) were devoted to the analysis of documents and their influence on teacher education and practice. Among the issues addressed are the National Curriculum Guidelines (DCNs) for professional development, the appropriation of the curriculum innovation discourse, the conceptions about evaluation, the teachers' thoughts about curriculum proposals, and the influences of the curriculum in the institutional context. Evasion and the profile of students in undergraduate courses were the themes of four articles, and Enem, of five. This focus has revealed a variation in incidence over time. While Francisco, Alexandrino, and Queiroz (2015) identified 11 percent of theses and dissertations in this line between 2000 and 2008, Bejarano and Carvalho (2000) score around 45 percent of theses and dissertations in the period between 1972 and 1995. Regardless of these variances, the fact is that the recent Common National Curricular Base (BNCC) and high school reform will bring substantial modifications in schools, directly influencing classroom teaching, including affecting the workload and hiring of chemistry teachers. Although research in the period investigated has not yet covered these issues, they are emerging and will have direct consequences for initial training, which is worth further investigation.

Articles concerning the history and nature of science accounted for 7.5 percent. The publications were divided into epistemological issues, the nature of science, and history, including analysis of the subject in books. The history of science in the classroom, however, is poorly portrayed. Research whose objects were theses and dissertations show that this theme historically presented in a similar proportion to that found here,

whether in the teaching of chemistry (DELIZOICOV; SLONGO; LORENZETTI, 2013; FRANCISCO; ALEXANDRINO; QUEIROZ, 2015) or science in general (MEGID NETO, 2007). In countertrend, Cachapuz *et al.* (2008) identified philosophy of science as one of the dominant lines in the international scenario. This may reflect the inclusion of a journal focused on this theme - *Science & Education* -, since the study of Tsai and Wen (2005), for example, recorded similar data to those portrayed here.

A current theme concerns cultural diversity - gender, sexuality, race, inclusive education - which accounted for fifteen articles - 4.5 percent of publications. This is a relatively recent focus in interest in science and chemistry education, barely appearing in previous national (BEJARANO; CARVALHO, 2000; FRANCISCO, ALEXANDRINO; QUEIROZ, 2015) or international (CACHAPUZ *et al.*, 2008; TEO; GOH; YEO, 2014; TSAI; WEN, 2005) surveys. While the need for debates on issues of tolerance and diversity grows, Research in the Teaching of Chemistry, based on this approach, still has little representation and is necessary.

The topics educational technologies and non-school spaces were the two least researched, respectively with seven (3.4 percent) and four articles (1.9 percent). The publications on technologies focused predominantly on the performance and conceptions of the basic education teacher (5), as well as on the analysis of didactic and pedagogical potentialities. There is a lack of papers focusing on pedagogical practices. Tsai and Wen (2005) also listed these themes as less representative.

However, in the case of technologies, there is a recent growth trend, as evidenced by data from Teo, Goh e Yeo (2014). It is possible that there is an increase not yet verified in the period delimited, due to the rapid expansion of social media and popularization of smartphones. This is corroborated by the data showing seven out of twelve articles published after the year 2013. Santos and Silva's (2019) survey on technologies for teaching physics indicate this direction, with a growth trend starting in 2014. Silva and Mercado (2020) reveal high incidence of research on the theme of digital labs and interfaces from 2010 onwards.

The theme on non-school spaces exhibited low representativeness, but with a slight growth trend in relation to previous periods (FRANCISCO; ALEXANDRINO; QUEIROZ, 2015). International studies (CACHAPUZ *et al.*, 2008; TEO; GOH; YEO, 2014) also point out the low incidence of this focus, signaling a gap in a subject that could contribute to understandings about the interests and more democratic access to scientific knowledge.

By aligning the indicators of thematic focuses with the research subjects, the data indicate an agenda of PEQ in Brazil focused on empirical studies and concerned with issues of teaching/training of undergraduates and with teaching practices and knowledge. There is a predominance of qualitative studies and studies about learning, which have received contributions from different points of view.

Final considerations

Historically constituted in the early 1980s, Research in the Teaching of Chemistry has been showing growth, especially since 2009, placing itself as the third most representative

in the field of natural sciences (12.2 percent), which presents a predominance of physics teaching (16.1 percent) and biology (13.8 percent). The temporal trends support the hypotheses of Megid Neto (2007), who predicted greater balance between chemistry, biology, and physics. More equality is projected for the future, although a stabilization in the number of publications can be perceived in recent years, which seems to occur more as a function of limitations of journals to keep up with the growing scientific production.

The area shows a strong predominance of its production in regional terms - Southeast -, of federative units - São Paulo, Rio Grande do Sul and Minas Gerais - and institutional terms - USP, UFMG and UFRGS -, besides a low international cooperation. However, it is possible to unveil some new trends. Among them, the growth of the Northeast region, intimately due to the strengthening of postgraduation courses in the region. It is projected that in the next decade the representativity of the Northeast region will grow at levels similar to and even higher than that of the South region. Even so, the asymmetry presented needs to be on the agenda of the community, which can think of solutions, such as interinstitutional cooperation.

The quantitative growth of the works also allows us to point out gaps and more established themes. In this sense, in terms of participating subjects, research that focuses on undergraduate students, postgraduate students, and higher education teachers is still incipient. Higher education students and basic education teachers, on the other hand, are the most present, although one notices little participation of the latter group in a collaborative manner in the publications, a not isolated factor that contributes to the still small impact of school reality. Even though chemistry is a school subject only starting in high school - at least before the high school reform - it is necessary to invest in a better understanding of its teaching from the beginning of the school period, where it starts and where curiosity and interests can be potentiated, as well as at the higher level, the stage in which new teachers are trained.

In terms of research content, the focus is on studies about pedagogical practices and learning. Despite the growth of the debate around diversity, technologies, and non-schooling spaces, these themes were not very representative and scattered. It is possible that the period analyzed did not cover some trends.

Among the challenges, there is still undoubtedly the greater participation of school institutions in the production of knowledge, in order to more effectively impact classroom teaching. Undoubtedly, this does not depend on the researchers per se, but it is a discussion of public policies and guidelines, which makes the challenge even greater. The need for greater international collaboration, circulating the knowledge produced in Brazil, can also broaden horizons, as can more systematic studies on themes that are increasingly discussed in today's society, such as technologies, cultural diversity, and non-school spaces. Thus, the data and considerations reported here can contribute to a better understanding of the area, from a panoramic view of already consolidated journals. Consequently, it is possible to trace paths for its growth, its strengthening, and its further consolidation.

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