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SOCIAL SCIENCES

Self-perceived competences by future chemistry teachers in Brazil

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Abstract: In this work we have compared the self-perceived competences of future chemistry teachers who are pursuing teacher training courses in all the regions of Brazil taking the following factors into account: sex, age and Brazilian region origin. A quantitative exploration was adopted and the data were collected using the Self-Perceived Competences of Teachers in Initial Chemistry Training (SPCTICT) instrument, composed of 21 items. An exploratory factor analysis enabled grouping the items into three factors: (a) self-perception of technical competences (knowledge), (b) Self-perception of competences linked to specific aspects (know-how) and, finally, (c) self-perception of generic competences (knowing how to act or how to behave). The results demonstrate statistically significant differences among men and women on the self-perception of their own competences regarding knowledge construction in chemistry.

Key words: gender, initial training, teachers, Chemistry, competences.

INTRODUCTION

The number of women working in chemistry continues to be lower than the number of men, particularly within professionals with post-graduation level degrees (Marasco 2005). Even though increasing numbers of women are pursuing chemistry as their major at the undergraduate level, it does not seem to reflect on the professor ratio within the academic career. The Brazilian context ratifies this downward trend in female representation as the level / prestige of the position increases. In the early stages of the career, there is fairness in the number of women and men. However, as positions progress, as in the case of productivity scholarships or the number of projects approved (by funding agencies) for female researchers, the percentage of women decreases considerably (Santos et al. 2019, Naidek at al. 2020, Oliveira et al. 2021).

Women in academic life face several additional barriers when compared with their male colleagues: the impact of maternity (Staniscuaski et al. 2021), stereotypes (Eaton et al. 2020) in the evaluation of their peer (Corinne et al. 2012) and the implicit bias (Handley et al. 2015). The bias against their own self-efficacy – the belief a person has in their own ability to resolve or to understand a particular problem or situation – is one of these biases which affects women in all areas, but particularly in jobs traditionally occupied by men. It particularly impacts women within scientific (Ross et al. 2022), technological, engineering, and mathematical (STEM) fields. In engineering, a study revealed that women students present a significant decrease in feelings of inclusion (Marra et al. 2009); among academic editors and editors-in-chief, women are even more underrepresented (14% and 8%, respectively) than among scientists - 26% of all (Liu et al. 2023).

The academic self-efficacy for women and students in STEM minorities is lower than that observed for men, although it is improved with mentoring (Macphee et al. 2013). The notion of self-perceived competence tends to be a much broader concept than self-efficacy (Rodgers et al. 2014): while self-efficacy is the belief a person has in his/her own ability to solve or understand a particular problem or situation, self-perceived competence or self-perception of competence is the self-perception of each person about their own competences and skills when these are applied in specific environments or situations. Based on this perspective, self-perceived competence encompasses the notion of self-efficacy (Bandura 1977). Studies have shown that, in STEM-related careers, women develop self-perceived competence through vicarious experiences, while men develop their self-perceived competence through mastery experiences (Owojaiye & Zuya 2016, Ogunyemi & Bamidele 2019). Essentially, this implies that men tend to receive greater motivation to construct belief in their ability and skills right from the basic education level (Elementary and High School), whereas women receive a great deal less overall; the impact of this lack of self-confidence in women can be observed in the pursuit of STEM courses or STEM-related career.

Considering that self-perceived competence is related to one's achievements (Hilts et al. 2018), it is primarily important to understand the underlying mechanisms involving the development of this self-perception. Most of the studies reported in the literature have been confined to the analysis of self-efficacy in the teaching of Chemistry (Ozgur 2021) and very few studies have been devoted to the analysis of self-perception of competences among students (Ferla et al. 2010, Mamolo et al. 2020); these few studies have confirmed the motivation of students to maintain and improve their skills in different areas, and this has been particularly observed during the COVID-19 pandemic (Portillo et al. 2020). When it comes to the teaching of chemistry, the differences in self-perceived competence observed between men and women still appear to be very subtle (Vincent-Ruz et al. 2018). This is presumably because self-efficacy and self-perceived competence share some conceptual similarities, and this makes the present study essentially relevant.

In addition to the differences between men and women, we also explore as an intersectionality the differences regarding regions where the students are located. Comparing the percentage of women and men with undergraduate, master, PhD fellowships and with graduate and undergraduate teaching positions, regional differences indicate the lowest participation of women in chemistry in the north and southeast (Naidek et al. 2019). Here we explore the perception of men and women as undergraduate students at the different regions of Brazil which can help in understanding the differences observed in the previous study.

In summary, this work is part of a broader research project whose main purpose is to investigate the interest of young people in STEM areas from school to university. In this context, we aim to obtain empirical evidence about possible differences in the self-perception of competences by future chemistry teachers according to the gender of the participants. Our questions are the following: are there gender-related differences in the self-perception of skills in undergraduate chemistry students when comparing the five geographic regions of Brazil? Can self-perceived competences, when analyzed according to gender, be influenced by the age of the participants?

The remaining part of the paper has been organized under the following sections: Context, Materials and Methods, Results and Discussion and Conclusions. In the context section, we present the reasons behind the use of Teachers in Initial Chemistry Training as the target of our investigation. We provide a detailed description of the methodology adopted for the conduct of this study in the Materials and methods section. We present the results obtained in the study along with discussions on the findings of our investigation in the Results and Discussion section. The final section is devoted to the conclusions drawn from the study and brief considerations regarding the potential application of the analytical instrument employed in this work for future studies.

CONTEXT OF INITIAL TEACHER TRAINING

Considered a heterogeneous, continent-sized country, Brazil has to deal with matters related to gender inequality in its various social strata, especially regarding the natural sciences (Anteneodo et al. 2020, Areas et al. 2022). One of these matters focuses on professional choices, leading to stereotypes interfering both in the choice for undergraduate courses in STEM areas as well as in career continuity by women who undertake them, as they are considered primarily male niches. This non-inclusive direction has been discussed (Olinto 2011, Reuben et al. 2014) and highlights the differences established between men and women in different professional areas and, above all, in the scientific field.

Unlike the developed countries which have more consolidated experiences in terms of the inclusion of STEM subjects in the school curriculum, Brazil is still working toward implementing a national education curriculum which offers STEM-integrated learning experience. This includes the organization of hands-on activities such as science groups, competition, camping, laboratories and the introduction of more modern topics in the curriculum. The current education curriculum in Brazil does not favor the effective inclusion of STEM subjects in the students' learning experience; the inclusion of STEM subjects has been limited to the individual initiatives of schools and teachers that are actively engaged in devising strategies to improve their teaching and students' learning experience.

Therefore we understand that this entire discussion goes through the training requirements of teachers who will work in basic education and can reverberate in chemistry curricula changes over the years, since this is a central science and, therefore, a gateway to STEM subjects (Winfield et al. 2020).

Efforts to improve education quality must begin by devising competent teachers, with appropriate boldness to reject any gender stereotypes in science teaching (Merdekawati 2018). Therefore, it is necessary to incorporate the development of these skills in the Brazilian chemistry teacher training. The National Common Curricular Base (NCCB) - a document that contains regulatory guidelines on what constitutes the essential education to be provided by teachers in Brazilian elementary and high schools, defines competence as follows (BRASIL 2018):

> "competence is defined as the mobilization of knowledge (concepts and procedures), skills (practical, cognitive and socio-emotional), attitudes and values to solve complex demands of everyday life, the full exercise of citizenship and the world of work."

Therefore, it is essential that chemistry teachers in initial training acquire distinct competences aligned with the inherent guidelines of their professional training while in their undergraduate courses. Research works dealing with the existing relationships between gender and future career perspectives can be found in the literature (Kang et al. 2018, Oliveira et al. 2019), however, to the knowledge of the authors, no studies were identified discussing self-perceived competences of future elementary and high school level chemistry teachers in the dimensions adopted and analyzed here in the light of the possible reflected differences in gender.

Self-Perceived Competences of Future Chemistry Teachers

According to Fonseca & Pereira (2019), the education and training of chemistry teachers must be structured based on a (new) rationality where the professionals are thoroughly prepared for the reality of the profession, with the implementation of a (new) strategy aimed at promoting theoretical and practical training centered on chemical knowledge, theoretical knowledge about Education, specific pedagogical practice and awareness creation regarding the political bias associated with teaching as a job. Generally, the idea of teacher training is associated with how people learn to teach and develop their practice over time (Feiman-Nemser 2008). Interestingly though, when we consider that competence is not innate but learnable, and, therefore, teachable (Wal et al. 2014), it becomes uniquely insightful to learn how future chemistry teachers in Brazil perceive their own competence when the following factors are taken into consideration: gender/sex, age and regional background.

Self-Perceived competence is understood here as individual self-perception over their own competences and skills when these are applied in specific environments or situations. It can also be assimilated as “a psychological variable that reflects people’s judgment about their own abilities to mobilize resources to achieve a certain objective” (Nobre & Valentini 2018). Thus, promoting studies that investigate the individual conceptions or predictions of a future chemistry teacher on their abilities and performance can provide evidence about their own empowerment regarding chemical knowledge and behavioral perspectives on their teaching performance – but only if behavioral and perceptional aspects are integrated in this process (Lee & Koh 2001).

When we think about the role of a chemistry teacher, there seems to be an inseparability between the term “competence” and the teacher training process which transcends curricular needs. The reason for this is the necessity for teachers to carefully know how to deal with professional knowledge toward a good performance of their functions when dealing with the process of teaching chemistry to their students. This happens precisely because chemistry is a central science with an abstract nature, which creates difficulties in its conceptual assimilation (Pozo et al. 1991) and is consequently considered a challenging discipline not only for this but for seldom relating with the daily lives of students (Sirvan 2007). Furthermore, chemistry involves representations of a macroscopic, microscopic and symbolic nature (Treagust 2015), that is, phenomena at the macroscopic level can be conceptualized in terms of submicroscopic entities and translated into symbolic representations (Wu 2003).

Given this perspective, it is noted that initial teacher training requires the acquisition of different fundamental skills to improve basic education, as the promotion of a curriculum containing competency-based approaches is more holistic and requires greater complexity due to the integration of techniques, strategies and interpersonal and emotional competence (Echeverría 2002) that need to be incorporated into the training of future chemistry teachers in Brazil. These will be utilized by them to face the challenge to help students think, make decisions and use specific strategies to face everyday problems in the classroom that are directly interrelated with chemistry. From this standpoint, this investigation adopts the understanding that competence is not, then, a skill or an achieved capacity, but rather a sense of confidence and effectiveness in action (Ryan & Deci 2002) Therefore, it is healthy to investigate how the new generation of chemistry teachers declares themselves in relation to their skills, and how their sex influence their effectiveness.

MATERIALS AND METHODS

In this study, the self-perceived competences of undergraduate Brazilian chemistry students have been investigated toward evidence possibly determined by the sex of university students. Sex is usually related to the biological aspect (Olinto 1998, Council of Europe 2022, Auhadeeva et al. 2015) being categorized as man and woman. Gender was coined to social, psychological, cultural and behavioral aspects of being a man, woman, (Money 1955, Heilborn 1994) or, more recently, other gender identities. The discussion of the distinction between sex and gender, however, is not free of controversies (Butler 1999). Here, we avoid this discussion by asking the questionnaire respondents what their sex is and by giving them a binary option: man or woman. Even though we separate the answers between men and women we are aware that the results are not only a function of their biological sex but of the social construction which starts even before they are born and has important elements in the elementary school years (Bian et al. 2017). Therefore, in the discussion of the results since we are analyzing the social consequences of the sex we refer to as gender which here has to be understood as "binary gender".

This study made use of a quantitative approach, using a limited set of statistical methods to try and standardize the analysis given the broad scope defined. In this way, the quantitative results were interpreted in order to answer the research questions.

As already mentioned, the questionnaire listed in the Appendix A was performed with university students from chemistry teacher training courses located in the five regions comprising the Brazilian territory. To this end, an investigative instrument was developed through a questionnaire aimed at ascertaining the self-perceived competences of students. The instrument called the "Self-Perceived Competences of Teachers in Initial Chemistry Training '' (SPCTICT) was composed of a questionnaire containing two sections and it was made available for four months. The first posed questions about the socio-demographic characteristics of the participants, raising information about sex, age and country region. The second questionnaire section contained 21 items with declarative statements on a Likert scale (Likert 1932) containing four response options with verbal description varying from strongly disagree to disagree, agree and strongly agree. According to Nadler et al. (2015) items on this type of scale with four to seven options exhibit greater validity and reliability. In addition, we chose not to include a neutral midpoint in the scale as a way of encouraging respondents to take an active position. The questionnaire was sent by email to the course coordinators of twenty-four Brazilian public universities (being three State and twenty one Federal) of all geographic regions of Brazil.

The construction of the SPCTICT was influenced by concepts outlined in the literature about the skills and challenges that can be perceived in the context of chemistry, in addition to the teaching experience of the main author in the area of Chemistry Education (Cleophas & Cunha 2020), studies related to professional competences (Gondim et al. 2003) and levels of chemical knowledge necessary to work in the area (Johnstone 1999). The draft Self Perceived Competences of Teachers in Initial Chemistry Training (SPCTICT) instrument was structurally analyzed for reliability, as well as externally tested to determine convergent and discriminant validity. While continued validation is necessary, the simplicity of the SPCTICT may be valuable because it presents potential for measuring gender disparities in relation to self-perceived competence of future chemistry teachers.

The definition of "competences" may involve some imbricated dimensions. Thus, we adopted in our study the understandings defended by Echeverría (2002), who posits they are related to professional skills involving technical issues (knowledge), methodological aspects (practical knowledge) and generic skills, also known as transversal skills, which can be further divided into two behavioral aspects (knowing how to act and knowing how to be).

Taking these observations into consideration, in the second section of the investigative instrument, the items were separated into categorical dimensions, which were referred to as factors; these factors constitute a set of three self-perceptions linked to competences. The factors were divided into the following:

- Factor 1: Self-perception of technical competences (knowledge);
- Factor 2: Self-perception of competences linked to specific aspects (know how to do);
- Factor 3: Self-perception about generic competences (knowing how to act / knowing how to be).

This last factor projects on the mobilization of necessary skills to generate the learning of chemistry in their future students.

Once the instrument execution was completed, the collected data were exported to a comma-separated-value (CSV) file so that the analysis could be done in the Python program (Oliphant 2007) via Pandas (McKinney 2010), Matplotlib (Hunter 2007) and Seaborn (Waskom et al. 2017) packages. It was necessary to convert the questionnaire responses toward generating a set of ordinal data. The intensity measured by the subjects regarding the assertions ranged from 1- Strongly disagree, 2- Disagree and 3- Agree to 4- Strongly agree. As part of data checking, how many students had answered all items with exactly the same answer was verified, as this would give us an indication if respondents would not be reading each item. Subsequently, an Exploratory Factor Analysis (EFA) was conducted in Python, followed by an analysis of the reliability of the factors adopted in this research, and subsequent comparisons between the means related to the many variables and factors altogether with the combined factors. The EFA is a statistical technique that reduces a large number of variables, transforming them into a smaller set of factors where each is related to a latent construct that cannot be directly measured.

Through EFA, we attempted to understand how to group the various items of the instrument into the latent variables. Such analysis proved to be appropriate, since the number of research participants was higher than what is generally recommended (300 participants), coupled with the fact that the ratio between the number of participants and the number of Likert items was greater than 30:1 – much higher than the recommended minimum ratio of 10:1 (Costello & Osborne 2010). To explore the reliability of these various factors, internal consistencies were measured using Cronbach's alpha coefficient, often used to assess reliability when concepts are operationalized through a construct (Christophersen 2009). Thus, we obtained a Cronbach's alpha value greater than 0.70 for two factors, which is considered acceptable (Nunnally 1978) and a value of 0.64 for the third factor. This result was not a problem, since the total variability explained by this factor is minor (Tavakol & Dennick 2011). The T-test - for the sex variable, the ANOVA test - for region variable and the Kruskal-Wallis test[1] (Kruskal & Wallis 1952) - for age variable - were employed for the analysis of the differences between the mean scores of the different groups. Finally, we analyzed the difference between the mean scores obtained for each factor and the correlation between them - taken in pairs.

This research was approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul (UFRGS) nº 04347418.9.0000.5347. All the participants received the questionnaire along with an explanatory sheet on the project details and the protection of the participants' rights applicable to the sample group (students of a university teacher training course in chemistry of public institutions in Brazil). We used Google forms to construct the questionnaire used in this research and to receive the participants' opinions. The survey was sent to the coordinators of the selected courses, who voluntarily passed it on to the students. Therefore, the participants who agreed to take part in the study were asked to sign the consent form, which they sent along with the completed questionnaire.

RESULTS AND DISCUSSIONS

Profile of the Questionnaire Respondents

First, we analyze the profile of the 636 respondents of the questionnaire, all of them undergraduate students of chemistry. The Likert scale-based instrument was analyzed using the quantitative method. The percentages of responses for all items can be found in Appendix B. In all, 636 participants from all five geographic Brazilian regions participated in the survey, 409 of them being women (64.30%) and 227 men (35.70%). These results can be seen through Table I, which show in detail the distribution of participants by sex, age and region.

Clearly, the most common respondent profile are women between 19 and 24 years old living in the Northeast region of Brazil. Table I shows that.

Within the undergraduate students being trained to become teachers in chemistry, there are 60% of women and 40% of men (Nunes et al. 2020), which is consistent with the percentage of women respondents to our survey. The percentage of women in the field drops to 36% as professors teaching graduate courses (Naidek et al. 2020). Regarding the teachers at high school level in chemistry there is no available data discriminated by gender for the country, but in the most populated state, São Paulo, the percentage of women teachers is 56% (Nakamura 2022).

The Brazilian population is divided in the different regions as follows: 9% in the North, 27% in the Northeast, 42% in the Southeast, 14% in the South and 8% Midwest[2]. The distribution of undergraduate students is: 8% in the North,

1 used to compare differences between three (or more) independent groups when the dependent variable is either ordinal or continuous, but not normally distributed.

2 https://ftp.ibge.gov.br/Estimativas_de_Populacao/Estimativas_2021/estimativa_dou_2021.pdf.

Table I. Distribution of students by region, sex and age.

		Number of students	% of students	
			In this survey	In Brazil
Sex	Female	409	64.30	60.03
	Male	227	35.70	39.97
Age	< 18	58	9.12	-
	19 to 24	409	64.31	-
	25 to 30	111	17.45	-
	31 to 36	46	7.23	-
	37 to 42	5	0.78	-
	> 43	7	1.10	-
Region	Midwest	90	14.15	8.12
	Northeast	241	37.90	27.35
	North	38	5.97	8.92
	Southeast	90	14.15	41.83
	South	177	27.83	13.78

19% in the Northeast, 46% in the Southeast, 17% in the South and 10% Midwest[3].

The percentages of answers to the survey coming from students from northeast and south are larger than the percentages of students studying chemistry in these regions. The difference is not too large to affect our main results.

Validation of the Statistical Analysis in the three selected Factors

Next, we group the answers in three factors when they correlate. We submitted the student responses to an Internal Consistency Analysis that involved calculating the reliability coefficients for the total score of the instrument and evaluating the item-total correlation coefficients. Due to all the criticisms regarding the equivalence given between Cronbach's alpha and the reliability/internal consistency of a given questionnaire, as well as regarding its possibly appropriate values, it was decided to expose those coefficients most used in the literature, namely: McDonald ω (which is derived by factor analysis and it may be obtained from items communalities); Cronbach α - the most common and poorly understood coefficient - under the assumption of uncorrelated item errors, it could be the reliability coefficient if and only if the variances and covariances of the expected scores on the items are all equal (Cronbach 1967, Cho & Kim 2015); Greatest Lower Bound (GLB) - related to the trace of the error inter-item covariance matrix and the variance of the sum score (Sijtsma 2009). For a more in-depth discussion of these coefficients, see for example Cortina (1993), Flora (2020), Sijtsma & Pfadt (2021), Cho (2021) and Malkewitz et al. (2023). All data are presented in Table II.

The same coefficients were obtained under the condition that each test item had been deleted together with the observed item-rest correlation coefficient (Henrysson 1963), that quantifies the relationship between two

3 https://abres.org.br/estatisticas/#:~:text=Ingressam%203.445.935%20alunos%20em,(9%2C6%25.

Table II. Reliability coefficients for all the questionnaire.

Estimate	McDonald's ω	Cronbach's α	Greatest Lower Bond
Point Estimate	0.800	0.792	0.885
95% CI lower bound	0.777	0.768	0.877
95% CI upper bound	0.822	0.814	0.910

variables (a given question and the sum of all other questions excluding the one of interest) and varies between +1 and -1. These quantities are shown in Table III.

Here, we consider the value of 0.20 as a lower limit, which allowed us to exclude four questions from our proposed instrument (SPCTICT): items Q04, Q14, Q17 and Q20. Such analysis was corroborated by the heatmap of the correlations between the questions (see appendix C in SI), and also ratified by the EFA of the subsequent section. This is because such an analysis depends on the correlation pattern between the observed variables, although it is expected that statistically independent variables do not contribute to a common factor construction. With the exclusion of the four questions, there was a small increase in the value of all reliability coefficients (ω = 0.829; α α=0.822; GLB = 0.891), thus confirming the pertinence of the adopted exclusion.

With the seventeen remaining questions composing the SPCTICT instrument, Bartlett's sphericity test was performed first to verify whether the observed variables (items of the elaborated instrument) were correlated when using the comparison between the correlation matrix and the identity matrix. As a result, the Bartlett test presented a p-value equal to zero, indicating a statistically significant sample; in other words, the observed correlation matrix is different from the identity matrix.

The next step before applying a factor analysis was to verify whether the data set was capable of factoring. For this, the application of the Kaiser-Meyer-Olkin (KMO) criterion, also known as the sample adequacy test, is indicated. It is calculated using the square of total correlations divided by the square of partial correlations (Ford et al. 1986). The KMO values range between 0 and 1; consequently, values less than 0.60 were considered inadequate. The general KMO value was 0.88, therefore being considered favorable for the factor analysis.

In sequence, the EFA was conducted using the Python Factor Analyzer module (Biggs 2022) with the main axis factoring as a method of extracting factors, since the data showed a non-normal distribution by the Shapiro-Wilk test (1963). The chosen rotation method was oblique, 'promax', since this allows factors to be correlated. After the EFA, question Q07 was excluded because of its low factor load, and two other questions (Q03 and Q12) were also excluded because they presented low commonality (less than 0.25) (Costello & Osborne 2010). Commonalities are useful to evaluate the performance of the model: values closer to one indicate that the model explains most of the variation for these variables. Out of the total 21 questions composing the original instrument, 07 were eliminated and 14 items of the survey were retained for subsequent analysis, providing greater robustness to the SPCTICT instrument. Hence, the choice for the number of factors could be made either through the Kaiser criterion (Kaiser 1960) or the slope graph, both based on eigenvalues. Keeping the same number of factors when eigenvalues exist and are greater than 1 is also suggested. These three factors explain 49.43% of the total variance, representing a satisfactory result (Tinsley & Tinsley 1987). The

Table III. Reliability coefficients for each deleted item and item-rest correlation.

Item	If item dropped			Item-rest correlation
	McDonald's ω	Cronbach's α	Greatest Lower Bound (GLB)	
Q01	0.788	0.780	0.876	0.412
Q02	0.787	0.779	0.878	0.437
Q03	0.786	0.778	0.878	0.454
Q04	0.824	0.817	0.895	-0.122
Q05	0.795	0.789	0.882	0.304
Q06	0.791	0.783	0.881	0.361
Q07	0.780	0.772	0.873	0.565
Q08	0.787	0.779	0.877	0.475
Q09	0.779	0.772	0.870	0.533
Q10	0.781	0.774	0.876	0.532
Q11	0.779	0.771	0.874	0.553
Q12	0.785	0.777	0.875	0.463
Q13	0.796	0.789	0.874	0.271
Q14	0.801	0.793	0.878	0.205
Q15	0.783	0.776	0.875	0.479
Q16	0.781	0.773	0.873	0.517
Q17	0.807	0.798	0.886	0.091
Q18	0.788	0.779	0.878	0.429
Q19	0.794	0.786	0.878	0.322
Q20	0.815	0.805	0.891	0.058
Q21	0.791	0.782	0.879	0.374

corresponding instrument items are presented with them in Table IV.

The first factor relates to the self-perception of each respondent about their own technical competences (knowledge), while the second factor indicates their self-perceived competence related to certain abilities/aspects of knowledge in the field (know-how). The third factor expresses their self-perception on generic competences (knowing how to act / knowing how to be). These results indicate that students see competences related to knowledge differently from competences characterizing specific abilities (know-how) and generic competences (knowing how to act / knowing how to be), even though all three dimensions about competences (here adopted as factors) are part of their own scope concerning self-competences on chemistry knowledge.

The internal consistency of each factor was assessed using the same reliability coefficients (ω, α and GLB). The relatively low values for the "generic competences (knowing how to act / knowing how to be)" dimension can be considered satisfactory, since this factor explains the lower variance rate (14.50%). Our values for all three factors are shown in Table V.

Based on the sample size (over 600 respondents), the non-normality of the factor average scores does not matter when making inference about the population. Thus, after verification of homoscedasticity (indicating the inequality of variances), differences in the mean scores were examined using the One-Way Welch ANOVA (Welch 1951), which indicated

Table IV. Items, factors and factor loadings related to student self-perception about their chemistry skills.

Factors and Items	Factor loadings		
Factor 1 (F1): Self-perception of technical skills (knowledge)	**F1**	**F2**	**F3**
I find it easy to perform chemical experiments in a laboratory class;	**0.65**	0.13	-0.19
If I went to a museum, I would easily identify what is being shown about chemistry;	**0.61**	0.04	0.00
If I wanted to, I could be good at researching chemistry;	**0.83**	0.00	0.00
If I study, I can be successful on a chemistry test;	**0.58**	0.00	0.05
I know how to relate theory to practice when I'm performing experiments in the laboratory;	**0.52**	0.18	0.09
I can interpret graphs when present in a chemical problem;	**0.45**	0.29	-0.39
Factor 2 (F2): Self-perception of skills linked to specific aspects (know-how)			
I can easily solve stoichiometric calculations;	0.06	**0.83**	-0.08
I easily understand the differences between ionic, covalent and metallic bonds;	0.20	**0.46**	0.15
I prefer chemical questions that have calculations;	-0.23	**0.79**	-0.05
I know how to balance chemical equations easily.	0.04	**0.70**	0.02
Factor 3 (F3): Self-perception of generic competences (knowing how to act / knowing how to be)			
I like chemistry;	-0.02	0.27	**0.54**
I always establish connections between different common everyday situations and chemistry;	0.07	0.09	**0.54**
As a future teacher, I understand the importance of knowing how to use technologies in the classroom;	0.00	-0.24	**0.85**
I like the idea of becoming a chemistry teacher.	-0.09	-0.01	**0.81**

that the mean scores of the factors were significantly different ($p < 0.0001$ and Partial eta-squared = 0.147). Games-Howell post hoc test (Games & Howell 1976) (a proper post-hoc test to heterogeneity of variances) was used to understand the differences between each pair of factors adopted in the research. In addition, statistically significant differences were observed between the mean scores of the factor pairs F1 - F3 [p-value < 0.0001, d(cohen) = -0.89] and F2 - F3 [p-value < 0.0001, d(cohen) = -0.88], but no significant distinction was observed between factors F1 and F2 [p-value = 0.30, d(cohen) = 0.08]. These results indicate that factor 3 has the highest average score globally, suggesting that respondents were more likely to agree with generic competences (knowing how to act / knowing how to be) concerning their role as teachers, and that they are necessary to facilitate their future students into learning chemistry, revealing something quite salutary. F1 (theoretical skills – knowledge) had the second highest average score, while the second factor (skills competences regarding specific aspects – know-how) was in the last position, even with the overall average of the SPCTICT instrument. Opportunely, this also indicates a general agreement with it (since the maximum value of the average scores, according to our standardization of the Likert

Table V. Internal consistencies of the various factors.

Survey items	McDonald's ω	Cronbach's α	GLB
Factor 1 (F1): Self-perception of technical competences (knowledge)	0.694	0.691	0.742
Factor 2 (F2): Self-perception of competences linked to specific aspects of knowledge (know-how)	0.743	0.733	0.771
Factor 3 (F3): Self-perception of generic competences (knowing how to act / knowing how to be)	0.649	0.634	0.683

Table VI. Differences in average survey scores on the different factors.

Survey Items	Scores	Std. deviation
Factor 1 (F1): Self-perception of technical skills competences (knowledge)	3.064	0.434
Factor 2 (F2): Self-perception of competences linked to certain aspects of knowledge (know-how)	3.024	0.526
Factor 3 (F3): Self-perception of generic competences (knowing how to act / knowing how to be)	3.460	0.455
Entire survey (SPCTICT)	3.142	0.388

scale, would be 4.00), as the results demonstrate in Table VI.

Differences in sex, region and age in the three factors

Then we analyze how the profile of the three factors differs when sex, age and region are taken into account. Imbalances throughout the mean scores of the SPCTICT instrument were examined using the t-test for the variable “sex”, the ANOVA/F-test for variable “region”, and the Kruskall-Wallis test for variable “age” (for this variable, some groups are not large enough to perform parametric tests). The results are exhibited in Table VI and in Table VII.

First, we analyze how the answers in the three factors differ when the sex of the respondent is considered. The t-tests (applied to the sex variable) in the three factors indicated that there are significant differences between the average scores obtained by men and women in F1 (p-value = 0.015) and F2 (p-value=0.007). The results indicate that women have a lower agreement degree than men regarding self-perception about their own technical competences (knowledge) and competences linked to specific aspects (know-how) during the exercise of their profession, with no differences (compared to men) regarding self-perceived competences related to generic competences (knowing how to act / knowing how to be).

Next, we analyze the difference in the answers regarding the three factors when regionality is taken into account. Hypothesis tests were carried out in order to analyze differences related to the region in each of the three factors:

- In F1, given the equal variances obtained from the Levene test (Levene 1960), possible differences between the mean scores of all Brazilian regions were clarified by the ANOVA test (Fisher 1934), which indicated the inexistence of statistically significant differences in these regional subgroups. Finally, Tukey's test (Tukey 1949) confirmed the inexistence of these differences taken two by two.
- Regarding factors F2 and F3, different variances were obtained, leading us to the One-Way Welch ANOVA test (which is more reliable when the two samples have

Table VII. Differences in mean scores for the "Sex" categorical variable.

Factor	Female	Std. dev.	Male	Std. dev.	p-value	Hedges' g*	Power
F1	3.093	0.672	3.167	0.684	0.015	0.202	0.687
F2	3.005	0.675	3.141	0.751	0.007	0.226	0.779
F3	3.621	0.543	3.690	0.527	0.670	0.035	0.071

*Hedges' g is a measure of effect size used when comparing different-size groups.

Table VIII. Differences in mean scores for the "Age" and "Region" categorical variables.

	Categorical variables										
Factor	Age						Region*				
	<18	19-24	25-30	31-36	37-42	>43	MW	NE	N	SE	S
F1	3	3.09	3.11	3.21	3.03	3.53	3.13	3.07	2.99	3.15	3.13
F2	2.97	3.04	2.96	3.12	2.57	3.33	3.06	3.02	2.79	3.01	3.06
F3	3.47	3.45	3.49	3.40	3.5	3.64	3.42	3.46	3.41	3.45	3.49

*MW = Midwest, NE = Northeast, N = North, SE = Southeast; S = South.

unequal variances and/or unequal sample sizes). In order to analyze the differences taken two by two, we used the Games-Howell test - very similar to the Tukey HSD post-hoc test but is much more robust to heterogeneity of variances.

All the tests mentioned above revealed the absence of statistically significant differences between respondents from different Brazilian regions, indicating that it was not possible to problematize the existing regional disparities in Brazil in our study without going into gender disparities (as we will see in the next section). The predominance of Degrees offered in Chemistry courses mostly by public institutions in Brazil, in some way, may resolve the disparities making the scenario, at university level, more homogeneous (or less inhomogeneous) than it would be at the elementary and high school level.

Taking the same sequence of steps that was performed for the previous categorical variables (Levene, hypothesis and post hoc tests), regarding the grouping by age, we noticed that the three factors lacked a significant difference between technical competence (knowledge) self-perception and respondents' age. This indifference between the self-perception of competences in general (related to all three factors) and the age of the respondent may be associated with a multiplicity of reasons: older age can be associated with greater life experience, more work experience, parenting experience, etc., but also with, for example, frustration due to the loss of a job. These factors can have very different effects.

Correlations Between Average Survey Scores for Different Factors

After performing the EFA while taking into account the possibility of correlations between the three adopted factors in this research, we verified them once again for correlation in pairs and and by sex in order to identify if the differences in the factors regarding sex are driven by a common mechanism or they come from different sources (Figure 1).

Higher correlation values (greater correlation coefficient) in each pair of mean factor scores among men than among women is noticeable in notoriously in the last two graphs, indicating

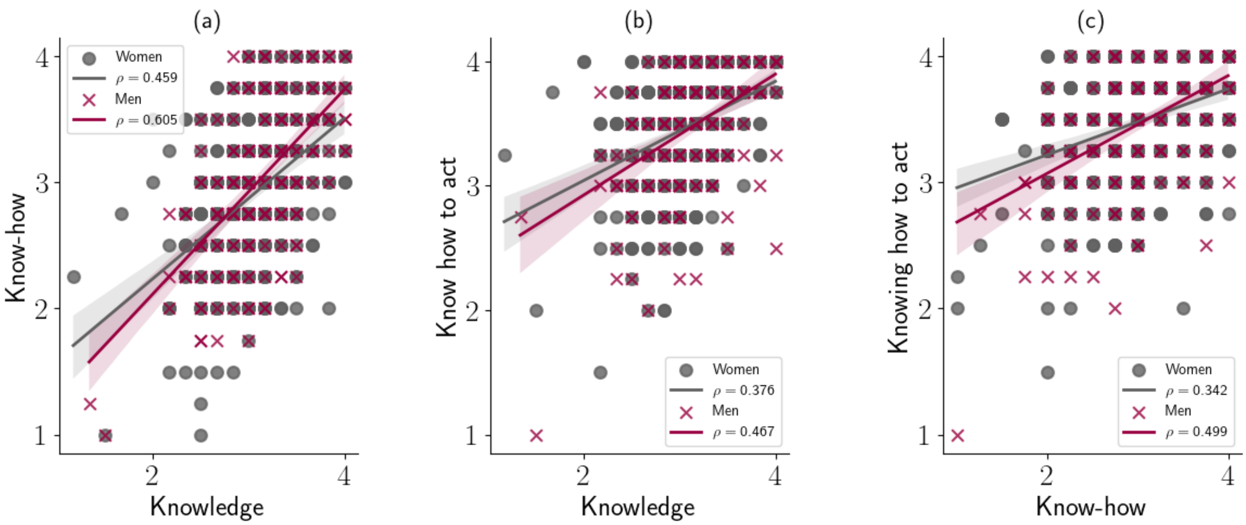

Figure 1. Correlation between pairs of factors discriminated by sex. Men are illustrated by purple crosses and women by gray circles. The purple solid line shows the best fit for the purple crosses and the gray line for the gray circles.

an existing difference between the pairs of factors (F1 and F3) and (F2 and F3) which had already been previously reported when we dealt with the differences between the mean scores of the factors, without discriminating them for any categorical variable. The r family effect sizes (of which Pearson's correlation coefficient is a part) describe the proportion of variance that is explained by group membership (Lakens 2022). Based on this observation, one can conclude that the association between a positive self-perception of technical competences (knowledge), competences linked to specific aspects (know-how) and generic competences (knowing how to act / knowing how to be) is stronger in men than in the group formed by women during chemistry training. This result is similar to that found by Sobieraj and Krämer (2019) which demonstrated that men presented greater self-efficacy over their skills when compared to women.

Afterwards, we have obtained the correlation between each of the three factors and the entire questionnaire, in order to assess the general agreement of the three factors in representing the construct. The result is shown in Figure 2, indicating strong correlation (correlation coefficient basically lying in the range of 0.70 to 0.90).

As the categorical variable "Sex" was the only one to present statistically significant differences, it was decided to scrutinize the correlations between the factors broken down by gender, and keep each graph representing each subgroup of the Region and Age variables. Figure 3 illustrates, with a linear regression graph for each Brazilian region, the correlation between the factors discriminated by sex. We can discern a greater gap between matches obtained by men and women in the north and southeast regions by analyzing the correlation between F1 and F2 (Fig 3a).

Analyzing the correlation between F1 and F3 (Fig 3b), on the other hand, clearly reveals that men and women have very similar profiles in the northeast and more discrepant in the southeast concerning the relationship between self-perception related to technical skills (knowledge) and that related to generic competences (knowing how to act / knowing how to be). Noticeably, examining the correlation between factors F2 and F3 (Fig 3c), men tend to establish a more direct connection between

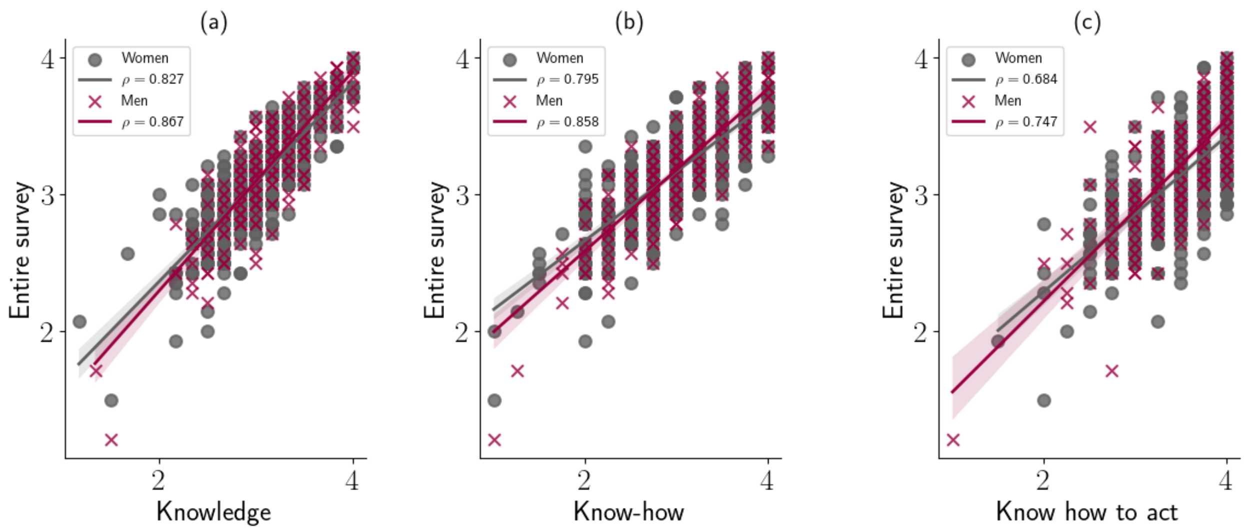

Figure 2. Correlation between each factor and the entire questionnaire.

their Self-perception of competence linked to certain aspects of chemistry (know- how) and their generic competences (knowing how to act / knowing how to be) in every geographic region of the country.

Figure 4 shows the correlations, with a linear regression graph for each age range, between factors discriminated by sex. We observed that the difference between the self-perception of competence linked to certain aspects of knowledge (know-how) and the self-perception of technical competences (knowledge) is evident in younger girls up to 18 years old; as can be noted in the graphs, there is a positive difference between this group (of younger girls) relative to men. This result (a greater slope of the linear regression curve) of the younger women when compared with older possibly points to the changing social roles of women in the 21st century among the younger generations: younger women tend to suffer less from the stigmas of sexism, being more self-confident in their own abilities. Then, it would be easier to induce change in this generation when compared with others. The age group that recorded the greatest disparity between men and women was the age of 31 and 36 years. Presumably, this outcome may be attributed to motherhood, which is associated with the same age group for women, impacting the progress and permanence of women in scientific careers (Machado et al. 2019).

Regarding the correlation between F1 and F3, we can infer that the greatest discrepancy between men and women concerns the age group of 25 to 30 years old, as men tend to show a greater correspondence than women between their own technical competences (knowledge) and their generic competences (knowing how to act / knowing how to be) in relation to acting in the teaching career. It is wholesome to stress that this behavior is reversed in the later age group (31 to 36 years old). Ultimately, while analyzing the correlation between F2 and F3, we realized that men and women exhibit very similar behavior until the age group of 25 to 30 years old. Posteriorly, a robust departure from the behavior of male teachers in initial training, when compared with women, begins with the self-perception of competences related to specific aspects (know-how) and to generic competences (knowing how to act / knowing how to be) during their career; in the contiguous age group (31 to 36 years), it returns to similarity.

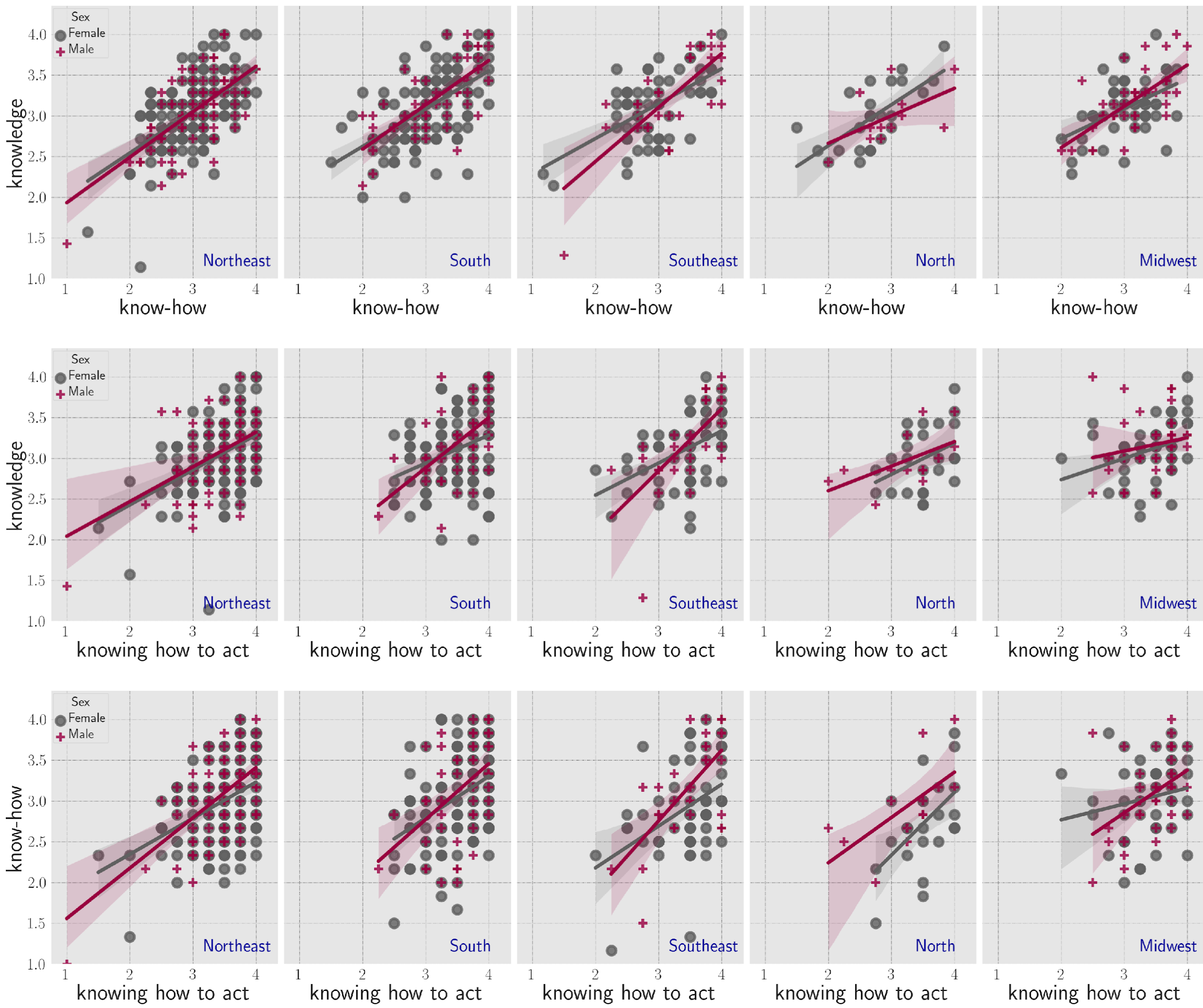

Figure 3. Correlation between (a) F1 (knowledge) and F2 (know how to do), (b) F1 (knowledge) and F3 (knowing how to act), (c) F2 (know-how) and F3 (knowing how to act) discriminated by sex and region. Men are illustrated by purple crosses and women by gray circles. The purple solid line shows the best fit for the purple crosses and the gray line for the gray circles.

CONCLUSIONS

The present work evaluated the self-perception of technical competences (knowledge), competence linked to certain aspects of knowledge (know-how) and generic competences (knowing how to act / knowing how to be) among Brazilian future chemistry teachers who are currently undergoing teacher training program in chemistry. The SPCTICT instrument, which contained the questions used for the survey, was subjected to reliability and validation analyses. Overall, the results obtained point to the existence of statistically significant differences between men and women in terms of the self-perception of their competence related to knowledge construction in chemistry; essentially, the results obtained show that men are more confident than women when it comes to demonstrating their knowledge of this subject.

The results obtained from the analysis of correlations between the mean scores of the three factors based on the categorical variable "region" pointed to a higher

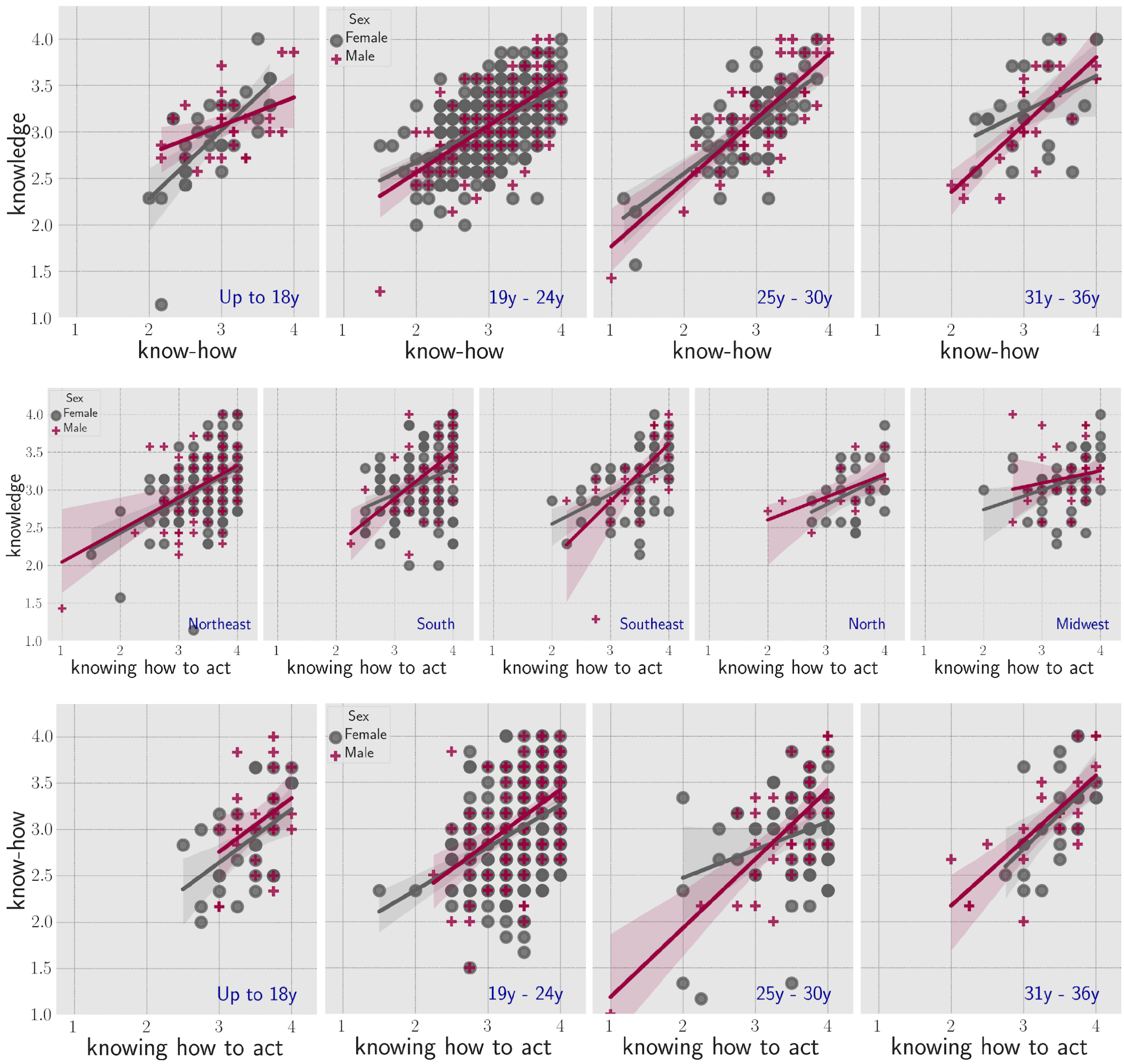

Figure 4. Correlation between (a) F1 (knowledge) and F2 (know how to do), (b) F1 (knowledge) and F3 (knowing how to act), (c) F2 (know-how) and F3 (knowing how to act) discriminated by sex and age. Men are illustrated by purple crosses and women by gray circles. The purple solid line shows the best fit for the purple crosses and the gray line for the gray circles.

discrepancy between the levels of agreement recorded among men and women in the southeastern and northern regions of Brazil. These discrepancies may have socioeconomic origins. The Southeastern region of Brazil is the richest and most densely populated part of Brazil, while the Northern region of the country suffers from low population densities and low human development indices. In addition, differences in the curricular structure of the teacher training programs offered in the regions may lead to imbalances in the offer of subjects that contribute to the development and enhancement of the students' knowledge in chemistry; furthermore, these differences can also lead to poor training of the students in cases where the university professors are incapable of helping their students understand chemical phenomena and ensure smooth didactic transposition, along with versatility of teaching and the linking of scientific concepts to people's daily lives. With regard to age, the difference between the self-perception of the students' competence linked to certain aspects of chemistry (know-how) and the self-perception of their technical competences in chemistry is more evident among younger women, especially among girls under 18 years old; this can be attributed to the following factors: doubts regarding career choice, lack of interest in the teaching profession, change of course during the undergraduate program, in addition to possible judgments about their own ability, thus generating insecurities, among other factors.

Finally, while the SPCTICT instrument adopted in this research was found to be reliable for the analysis of the self-perception of competence of students undergoing teacher training program in chemistry, we believe that expanding the number of factors employed in the analysis - for example, the inclusion of socio-emotional competences, can help significantly improve the reliability of the instrument. Although the present study was confined to the Brazilian context, the results obtained from the study can be potentially useful for comparative analysis in future studies aimed at investigating the field of teacher training from the perspective of self-perception of competence. The findings of this study bring novel contributions to the fore in the sense that they provide useful insights into understanding the self-perception of competence among men and women who are undergoing teacher training courses meant for the training of chemistry teachers who will be teaching in elementary and high schools. The promotion of specific awareness of the community might drive changes (Stockard et al. 2018).

STUDY LIMITATIONS

While it is true that the use of investigative instruments based on a Likert scale for the study of self-perceived competence brings insightful contributions toward the improvement of our understanding of the subject matter, it is clearly reasonable to recommend that the results presented here should be objectively interpreted with some degree of analytical prudence. The present study adopted factors that are directly connected to discussions on the understanding of "competence", the definition of which may vary according to the field of study; as such, this observation must be taken into account when analyzing the findings of this study. Another factor that may be considered a limitation to our research has to do with the sample employed in the study; although the sample is seemingly significant, it is not uniform in terms of participant distribution: women represented almost two thirds of the total number of respondents, and the number of respondents from the most populated southeastern region of Brazil did not reflect the weight of this region in the sample population. In addition, we do believe that the use of a single analytical methodology also limited our findings. Clearly, the combined application of both quantitative and qualitative methods would make the SPCTICT instrument much more robust and richer, as it would help us make field notes and conduct interviews with the respondents and focus groups, thus allowing a greater possibility for the investigated subjects to express their individual or group opinions. The instrument designed for this research called "Self-perceived Competences of Teachers in Initial Training in Chemistry" (SPCTICT) also presents a restriction since its validation could have been previously performed through discussions with experts to evaluate the relative impact of its probable contributions. Finally, for the continuation of our research, we aim to perform a meta-analysis of studies on the training of chemistry teachers taking into account not only the differences in self-perceived competence but also sex-related differences which may play an influential role in shaping the self-perception of future chemistry teachers pursuing teacher training courses in the country.

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Appendix A. Survey Instrument.

We invite you to participate in the research entitled "Interest in the areas of Science and Technology: from school to university" linked to the Graduate Program in Science Education: Chemistry of Life and Health at UFRGS, with the collaboration of Professor Márcia Barbosa and developed by Dra. Maria das Graças Cleophas Porto. The research will be developed in the year 2020 and its main objective is to evaluate gender relations in relation to the learning of basic concepts of Chemistry and, within this theme, to verify if there are differences between the performance in the learning of women and men under the aegis of the chemical knowledge.

To participate in this study, you will have no cost and you will not receive any financial advantage. The time required to complete the questionnaire is five minutes. Your participation in this survey is voluntary and, under no circumstances, mandatory. You can give up at any time, as you are free to refuse to answer questions that cause any kind of embarrassment. This survey has minimal risk, and only fatigue may occur in relation to completing the online questionnaire. If this occurs, feel free to continue with the activity or not.

We guarantee the anonymity of your answers and the collected data will be analyzed for academic purposes only, such as the publication of scientific articles, complete works in the annals of events or presentation of seminars. This questionnaire was approved by the UFRGS Ethics Committee. For clarification, you can go to the UFRGS Research Ethics Committee at the following address: Paulo Gama Avenue, 110 Campus UFRGS, Porto Alegre – RS, Brazil.

1. Free and clarified consent

( ) I agree to participate in this research.
( ) I don't agree to participate in this research.

2. Sex:

( ) Female
( ) Male

3. From which Brazil's region is your undergraduate course in Chemistry?

( ) Northeast
( ) South
( ) Southeast
( ) Midwest
( ) North

4. Whats' your age:

( ) Up to 18 years old
( ) 19 - 24 years old
( ) 25 - 30 years old
( ) 31 - 36 years old
( ) 37 - 42 years old
( ) Over than 43 years old

The items below are affirmative sentences. Inform your degree of agreement in relation to each item.

5. I find it easy to perform chemical experiments in a laboratory class.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

6. If I went to a museum, I would easily identify what is being shown about Chemistry.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

7. I help my classmates solve Chemistry problems on a list of exercises.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

8. I feel anguish when they think about trying to solve difficult chemistry problems.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

9. If I wanted to, I could be good at doing research on chemistry.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

10. If I study I can be successful on a Chemistry test.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

11. I understand the differences between atomic models.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

12. I like chemistry.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

13. I can easily solve stoichiometric calculations.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

14. I know how to relate theory to practice when I'm doing experiments in the laboratory.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

15. I easily understand the differences between ionic, covalent and metallic bonds.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

16. I find it easy to use the balance in the laboratory.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

17. I prefer calculus-based chemical questions.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

18. I prefer to solve theoretical chemistry questions.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

19. I can interpret the graphs when present in a chemical problem.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

20. I can easily balance chemical equations.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

21. Chemistry is a male science.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

22. I always establish relationships between different common everyday situations with Chemistry.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

23. As a future teacher, I understand the importance of knowing how to use technologies in the classroom.

( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

24. Molecular compounds in water form ions.

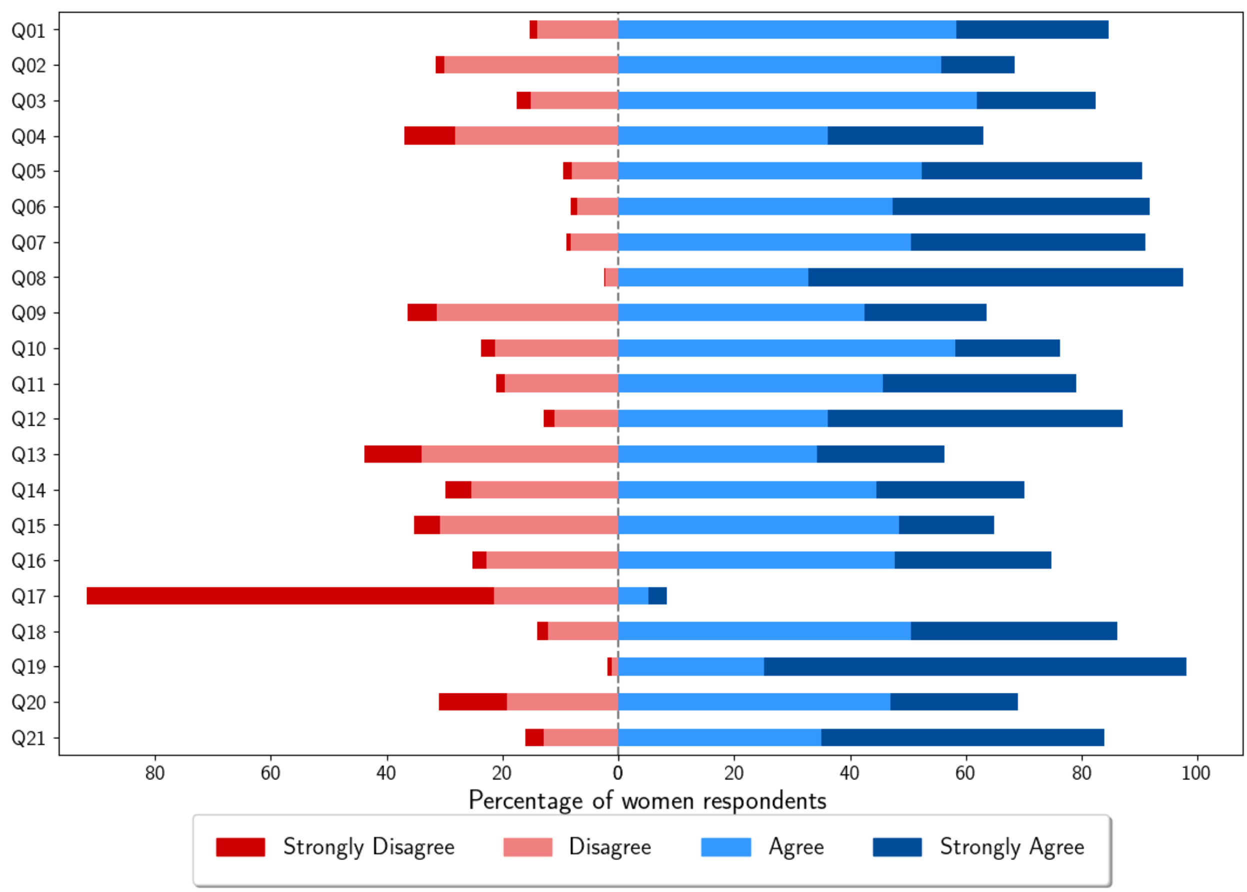
( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

25. I like the idea of becoming a chemistry teacher.

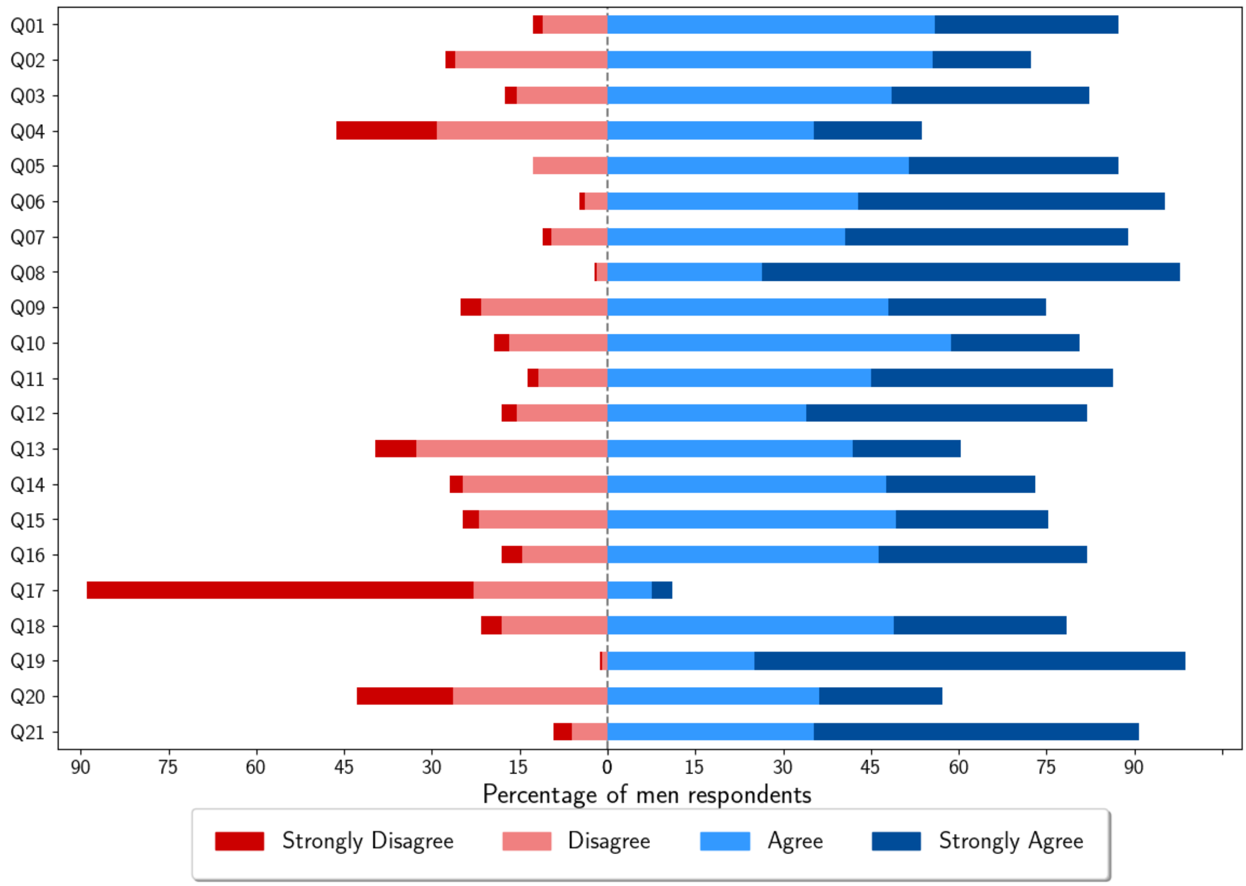
( ) Strongly disagree ( ) Disagree
( ) Agree ( ) Strongly agree

Appendix B. Likert Scale-based Instrument.

(a) Women responses



(b) Men responses



Appendix C. Heatmap for all 21 instrument items.

Appendix D. Brazilian Institutions that took part in the survey.

Universidade Estadual do Oeste do Paraná - UNIOESTE (campus Toledo)
Instituto Federal Goiano - IFGoiano (campus Morrinhos)
Universidade Federal de Goiás - UFG (campus Samambaia)
Universidade Federal do Paraná – UFPR (campus Curitiba)
Universidade Federal de Pernambuco – UFPE (campus Caruaru)
Universidade Federal do Triângulo Mineiro – UFTM (campus Uberaba)
Instituto Federal do Rio de Janeiro – IFRJ (campus Nilópolis)
Universidade de Brasília – UnB
Universidade Tecnológica Federal do Paraná – UTFPR (campus Medianeira)
Universidade Federal do Oeste da Bahia – UFOB
Universidade da Integração Latino-Americana – UNILA
Universidade Federal do Amazonas – UFAM
Instituto Federal do Amapá – IFAP (campus Amapá)
Universidade Federal do Rio Grande – FURG
Universidade Estadual de Santa Cruz - UESC
Universidade Federal Rural de Pernambuco – UFRPE
Universidade Federal de Roraima – UFRR
Universidade Federal do Acre – UFAC
Universidade Federal de Goiás – UFG/Goiânia
Universidade Federal de Minas Gerais – UFMG
Universidade Federal do Rio Grande do Sul – UFRGS
Universidade Federal do Rio de Janeiro – UFRJ
Universidade Federal da Paraíba – UFPB
Universidade Estadual Paulista – UNESP

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Author contributions

MGP worked on the conceptualization, methodology, data acquisition, writing of the original draft, and editing. MSM contributed with methodology, programming, software development, statistical data acquisition and analysis, writing of the original draft, review and editing. MCB worked on the conceptualization, methodology, writing review and editing, supervision, funding acquisition and project administration.