

# Self-perceived competences by future chemistry teachers in Brazil: a gender study

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In this work we have compared the self-perceived competences of chemistry teachers undergoing initial training in every Brazilian region regarding their sex, age and 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 competences (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

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women on the self-perception of their own competences regarding knowledge construction in chemistry.

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## 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.

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Women in academic life face a number of additional barriers when compared with their male colleagues: the impact of maternity (Staniscuaki 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, technological, engineering, and mathematical (STEM) fields. In engineering, a study

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revealed that women students present a significant decrease in feelings of inclusion (Marra et al. 2009).

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). Since self-efficacy is related to achievements (Tenaw, 2013), it is important to understand the mechanisms behind this process. Most of the studies involving questions regarding self-efficacy employ either a very limited number of respondents or a very homogeneous group from one regional area. Here, we attempt to expand the findings by analyzing a larger community located in a broader regional area.

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The remaining of this paper proceeds as follows: in the next section we will present a brief review of the references on self-efficacy and science and the reasons for focusing on Brazilian chemistry students to detect distinctions between men and women in self-efficacy. Next, in the Materials and Methods section, we display the instrument used to measure and understand the problem; then, the results and discussions are presented and analyzed. Finally, our conclusions will be presented.

## A REVIEW OF THEORETICAL REFERENCE ON SELF-EFFICACY

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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 et al. 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.

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Unlike developed countries such as the USA, Germany and Australia, all which have consolidated experiences in the educational field, Brazil is still slowly stepping toward inserting a curriculum that contemplates learning environments based on STEM education. In reality, this insertion is not encouraged by the Brazilian curriculum and is limited to individual initiatives by teachers engaged in improving their craft. However, 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).



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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. According to the National Common Curricular Base (NCCB), a document that regulates what is the essential education to be developed by teachers in Brazilian elementary and high schools (Brasil 2018).

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

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courses. Researches dealing with the existing relationships between gender and future career perspectives can be found in the literature (Kang 2018, Oliveira 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. Hence, the specific objective of the study described here was to highlight gender disparities in self-competence perception regarding the understanding of chemical knowledge between women and men in undergraduate courses offered by Brazilian public universities.

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In this context, the development of chemistry teachers must have a (new) rationality that manages to prepare professionals for their working reality and a (new) way of promoting theoretical and practical training that highlights chemical knowledge (Fonseca et al. 2019), theoretical knowledge about Education, specific pedagogical practice and the political bias concerning teaching as a job. However, when referring to teacher training, we generally refer to research on how people learn to teach and develop their practice over time (Feiman-Nemser 2008). Meanwhile, considering that competences are not innate, but learnable, and therefore, teachable (Wal 2014), it becomes

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quite unique to investigate how future chemistry teachers in Brazil perceive their own competence when their sex, age and country region are taken into analysis.

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

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chemical knowledge and behavioral perspectives on their teaching performance – but only if behavioral and perceptual aspects are integrated in this process (Lee & Koh 2018).

Teachers play an important role in the educational system by possessing the ability to transform the lives of their students and also positively influence their choice of a professional career. Thus, training chemistry teachers to be committed to a quality-based teaching practice in the Brazilian basic education will favor the development of critical citizens capable of reflecting on every condition surrounding them (Paiva & Olimpio 2014). On the other hand, the actuation of a chemistry teaching that may induce attitude shifts regarding adversities found in Brazilian society

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must undergo the teacher training process offered in university courses. It should be noted that universities in Brazil have autonomy and flexibility to build their training curricula as long as they meet the National Curriculum Guidelines for the Initial Teacher Training for Basic Education and, more recently, the Common National Base for the Initial Teacher Training Basic Education, which focuses on the founding principles of the NCCB.

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

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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 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).

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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



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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.

In this study, the self-perceived competences of undergraduate Brazilian chemistry students have been investigated toward possible evidence possibly determined by the sex of university students. It is worth emphasizing that the term “sex” will be employed instead of “gender”, as we are adopting the definitions given by the sociological literature (Auhadeeva et al. 2015) according to which the term “gender” is often used to distinguish “biological” sex and "social" sex. Therefore,

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our research took as a premise an investigation based on the anatomical and physiological differences between the subjects, that is, between the female and male sexes as informed by the subjects during data collection. 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 sex of the participants. Therefore, our questions are the following: are there sex-related differences in the self-perception of skills in undergraduate chemistry students when comparing the five geographic regions of Brazil?

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Can self-perceived competences, when analyzed according to sex, be influenced by the age of the participants?

## MATERIALS AND METHODS

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.

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As already mentioned, the questionnaire listed in the Appendix A (SI) 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 competencies of students. The instrument was called the “self-perceived competencies of teachers in initial chemistry training” (SPCTICT) and was composed of a questionnaire containing two sections. The first posed questions about the sociodemographic characteristics of the participants, raising information about gender (biological category), age and country region. The second questionnaire section contained 21 items with

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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 definition of “competencies” 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

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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).

Therefore, the instrument, the items were separated into three factors, which were used to identify empowerment in each subject due to their self-perception of important competencies corresponding to their understanding of chemistry, namely:

↵ Factor 1: Self-perception of technical competences (knowledge);

⊘ Factor 2: Self-perception of competences linked to specific aspects (know-how);

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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 packages. It was necessary to convert the questionnaire responses toward generating a set of ordinal data. The

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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



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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

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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 (Nunally 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 (Tavacol & Dennick 2011) To check the differences between the mean scores of the different groups (sex, region, age), the Mann & Whitney (1947) test (for the sex variable) and the Kruskal & Wallis (1952) test (region and age variables) were conducted. Finally, the difference between the average scores obtained for each factor and the correlation between them, taken in pairs, was analyzed.

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This research was approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul (UFRGS), nº 04347418.9.0000.5347. Along with the questionnaire sent to the participants, an explanatory sheet on project details and the protection of rights that applied to the sample group (students of a university course training for chemistry teaching) was included. All participants who agreed to be part of this study were asked to sign the consent form, which was returned with the completed questionnaire.

## RESULTS AND DISCUSSIONS

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## Profile of the Questionnaire Respondents

First, we analyze the profile of the 636 respondents of the questionnaire. 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 SI. 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.

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

		Number of students	% of students
Sex	Female	409	64.30
	Male	227	35.70
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
	Northeast	241	37.90

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North	38	5.97
Southeast	90	14.15
South	177	27.83

Clearly, the most common respondent profile are women between 19 and 24 years old living in the Northeast region of Brazil, and expressing agreement with the vast majority of questions.

**Validation of the Statistical Analysis in the three selected Factors**

# Self-perceived competences by future chemistry teachers in Brazil: a gender study

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**Keywords:** Gender, Initial Training, Teachers, Chemistry, Competences.

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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 coefficient for the total score of the instrument and evaluating the item-total correlation coefficients. Despite the criticisms of its attribution on scales subdivided by *a posteriori* factor analysis (Cortina 1993), the reliability coefficient estimate we adopted is Cronbach's alpha coefficient (Cronbach 1967) obtained through the Pingouin package in Python (Vallat 2018) which registered a value of 0.80 once the three subscales (which will be discussed in the next section) represented correlated aspects of a single global construct (Devellis 2012). Cronbach's alpha coefficient, in turn, estimates the total

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score variance proportion in the set of items attributed to the latent variable (common factor) underlying all items; therefore, it consists of a measure of the internal consistency of an instrument, and its maximum value is equal to the unit. Values above 0.70 are indicative of good internal consistency to use the scale in the comparison between groups, whereas values greater than 0.90 are necessary to its use in the comparison between individuals (Talim 2004). Additionally, the observed item-total correlation coefficient (Henrysson 1963) quantifies the relationship between two 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 II.



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Table II: Cronbach's alpha coefficients for each deleted item and corrected item-total correlation.

Deleted Item	Cronbach's alpha results	Corrected item-total correlation
Q01	0.78	0.41
Q02	0.78	0.44
Q03	0.78	0.45
Q04	0.82	-0.12
Q05	0.79	0.30
Q06	0.78	0.36
Q07	0.77	0.56
Q08	0.78	0.48
Q09	0.77	0.53
Q10	0.77	0.53

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Q11	0.77	0.55
Q12	0.78	0.46
Q13	0.79	0.27
Q14	0.79	0.21
Q15	0.78	0.48
Q16	0.77	0.52
Q17	0.80	0.09
Q18	0.78	0.43
Q19	0.79	0.32
Q20	0.81	0.06
Q21	0.78	0.37

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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, Q17, 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 Cronbach's alpha coefficient, becoming 0.82 and thus confirming the pertinence of the adopted exclusion.

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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

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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. 1983). 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, items with low factor load (questions Q04,

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Q07, Q14 and Q17) were excluded, and it was necessary to exclude three further questions (Q03, Q07 and Q12) given they presented low commonality (less than 0.25) (Costello & Osborne 2010). Out of the total 21 questions composing the original instrument, 07 were eliminated and 14 items of the survey were retained for subsequent analysis, thus providing greater robustness to the SPCTICT instrument. Hence, the choice for the number of factors could be made either through the Kaiser<sup>(1960)</sup> criterion 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.

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These three factors explain 49.43% of the total variance, representing a satisfactory result (Tinsley & Tinsley 1987). The corresponding instrument items are presented with them in Table III.

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

Factors and Items	Factor loadings		
	F1	F2	F3
Factor 1 (F1): Self-perception of technical skills (knowledge)			

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I find it easy to perform chemical experiments in a laboratory class;	<b>0.65</b>	0.13	-0.19
If I went to a museum, I would easily identify what is being shown	<b>0.61</b>	0.04	0.00
about chemistry;			
If I wanted to, I could be good at researching chemistry;	<b>0.83</b>	0.00	0.00
If I study, I can be successful on a chemistry test;	<b>0.58</b>	0.00	0.05
I know how to relate theory to practice when I'm performing	<b>0.52</b>	0.18	0.09
experiments in the laboratory;			
I can interpret graphs when present in a chemical problem;	<b>0.45</b>	0.29	-0.39
<b>Factor 2 (F2): Self-perception of skills linked to specific aspects</b>			
<b>(know-how)</b>			
I can easily solve stoichiometric calculations;	0.06	<b>0.83</b>	-0.08
I easily understand the differences between ionic, covalent and	0.20	<b>0.46</b>	0.15



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metallic bonds;			
I prefer chemical questions that have calculations;	-0.23	<b>0.79</b>	-0.05
I know how to balance chemical equations easily.	0.04	<b>0.70</b>	0.02
<b>Factor 3 (F3): Self-perception of generic competences (knowing</b>			
<b>how to act / knowing how to be)</b>			
I like chemistry;	-0.02	0.27	<b>0.54</b>
I always establish connections between different common everyday	0.07	0.09	<b>0.54</b>
situations and chemistry;			
As a future teacher, I understand the importance of knowing how to	0.00	-0.24	<b>0.85</b>
use technologies in the classroom;			
I like the idea of becoming a chemistry teacher.	-0.09	-0.01	<b>0.81</b>

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The first factor relates to the self-perception of each respondent about their own technical skills (knowledge), while the second factor indicates their self-perception regarding their skills parallel to specific abilities (know-how). Finally, 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-efficacy on chemistry knowledge.

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The internal consistency of each factor was assessed using Cronbach's alpha coefficient. The first two factors obtained an alpha value considered acceptable (Nunally 1978). The relatively low Cronbach's alpha value 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%). In the literature, the minimum Cronbach's alpha value indicated to be accepted as reliable is 0.60 in exploratory investigations (Hair et al. 2019) as is the case for the present study. These values for all three factors are shown in Table IV.

Table IV: Internal consistencies of the various factors.

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Survey items	Cronbach's alpha
Factor 1 (F1): Self-perception of technical skills (knowledge)	0.70
Factor 2 (F2): Self-perception of skills linked to specific aspects (know-how)	0.71
Factor 3 (F3): Self-perception of generic competences (knowing how to act / knowing how to be)	0.64

Differences in the mean scores were examined using the Kruskal-Wallis test (McKight & Najab 2010) since the mean scores presented non-normal behavior by the Shapiro-Wilk test (1963).

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Dunn's *post hoc* test (Dunn 1964) was used to understand the differences between each pair of factors adopted in the research. The average scores of the different factors were all significantly distinct at a 95% significance level, whereas we found statistically significant differences between the average scores of the factor pairs 1-3 and 2-3, without any significant distinction between factors 1 and 2 ( $p = 0.13$ ). 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. Factor 1

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(theoretical skills – knowledge) had the second highest average score, while the second factor (skills 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, as the results demonstrate in Table V.

Table V: Differences in average survey scores on the different factors

Survey Items	Scores	Std. deviation
Factor 1 (F1): Self-perception of technical skills (knowledge)	3.10	0.74
Factor 2 (F2): Self-perception of skills linked to specific aspects	3.02	0.80

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(know-how)		
Factor 3 (F3): Self-perception of generic competences (knowing	3.46	0.70
how to act / knowing how to be)		
Entire survey (SPCTICT)	3.02	0.88

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## 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

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using the Mann-Whitney test for the categorical variable “sex”, and the Kruskal-Wallis test for categorical variables “age” and “region”. The results are exhibited in Table VI.

Table VI: Differences in average survey scores on the different categorical variables.

Categorical variables													
Fact.	Se			Age					Region				
	x												
	F	M	<18	19-	25-	31-	37-	>43	M	NE	N	SE	S
				24	30	36	42	W					



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F1	3.0	3.14	3	3.09	3.11	3.21	3.03	3.53	3.13	3.07	2.99	3.15	3.13
	8												
F2	2.9	3.10	2.97	3.04	2.96	3.12	2.57	3.33	3.06	3.02	2.79	3.01	3.06
	8												
F3	3.4	3.47	3.47	3.45	3.49	3.40	3.5	3.64	3.42	3.46	3.41	3.45	3.49
	5												

The results indicate that, when considering all three factors, women have a lower agreement degree than men regarding self-perception about their own technical skills (knowledge), skills

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linked to specific aspects (know-how) and generic skills (knowing how to act) / knowing how to be) during the exercise of their profession, and this difference on self-perception can be considered statistically significant as it reaches a 99.90% significance level (p-value <0.01).

Regarding the first factor, there is a growing average agreement within the 37 to 42 years-old age group, a relatively large difference in relation to competence and self-perception in both young people emerging from adolescence and middle-aged adults. The Kruskal-Wallis test indicated a value of  $p = 0.08$ , that is, for a significance level of 95% ( $\alpha = 0.05$ ), we can conclude that there is

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no outstanding difference between self-perception related to technical skills (knowledge) and respondent age.

Respondents from the north and northeast Brazilian regions demonstrated a slightly lower average level of agreement regarding self-perception of their own knowledge-related competencies. However, for the case of the “region” categorical variable, the Kruskal-Wallis test resulted in a p-value greater than 0.05, indicating no statistically significant distinction in agreement regarding technical skills (knowledge) self-perception levels throughout the different regions of Brazil.

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When analyzing factor 2, three age groups manifested some disagreement regarding their skills linked to specific aspects (know-how): up to 18 years old, 25 to 30 years old and 37 to 42 years old. The relationship between age and agreement level was not statistically significant because the found p-values were greater than 0.05 (according to the Kruskal-Wallis test). Except for the northern region, where all respondents had a similar agreement level, this was corroborated by a lack of statistically significant differences as indicated by the test for agreement levels related to aspect-centered competence (know-how) in the different country regions with 95% certainty (since the found p values were greater than 0.05).

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In the third factor, the Kruskal-Wallis test indicated no relevant differences between agreement levels related to generic competences (knowing how to act / knowing how to be) during the exercise of the profession and the research participants in any age group and region in Brazil. Summarily, regarding the grouping by age, we noticed that the three factors lacked a significant difference between technical competence (knowledge) self-perception and respondent age. Similarly, the same is observed for the region grouping related to the three factors.

**Correlations Between Average Survey Scores for Different Factors**

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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 broken down by sex through the regression diagrams illustrated in Figure 1.

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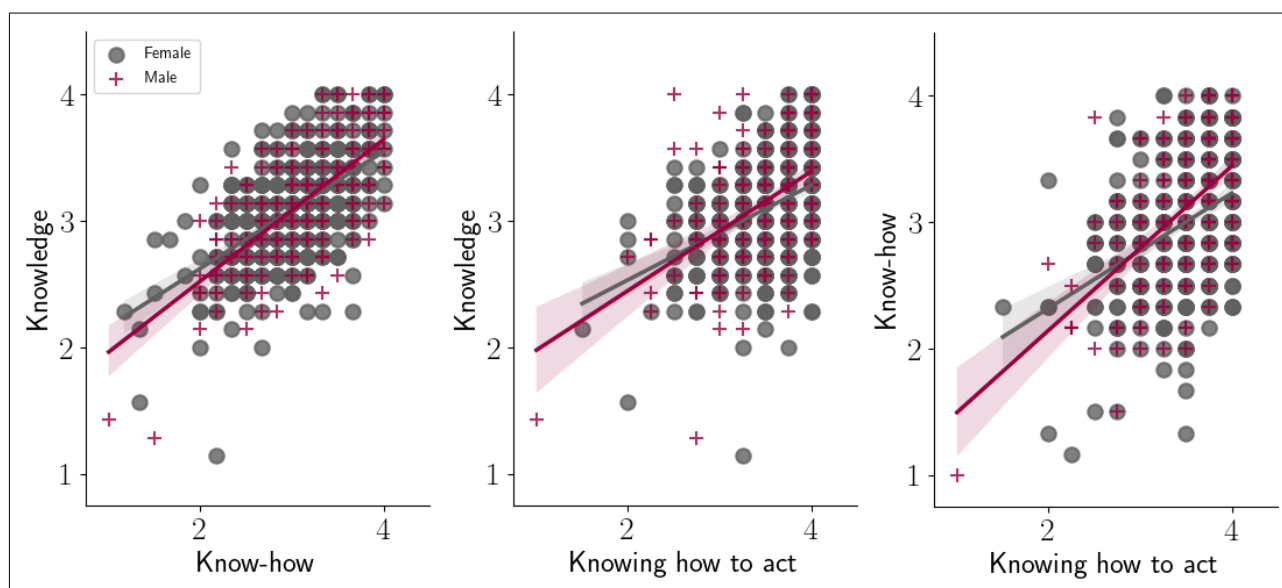
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Figure 1. Correlation between pair of factors discriminated by sex.

Higher correlation values (greater regression line slope) in each pair of mean factor scores among men than among women is noticeable in all three graphs. Hence, we 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.



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Figure 2 illustrates the correlation between the factors discriminated by sex and region. We can discern a greater gap between matches obtained by men and women in the north and southeast regions by analyzing the correlation between factors 1 and 2. Analyzing the correlation between factors 1 and 3, on the other hand, clearly reveals that men and women have very similar profiles in the northeast, and more discrepant ones 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) in the southeast. Noticeably, examining the correlation between factors 2 and 3,

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men find it easier to establish a connection between their own technical skills (knowledge) and their generic skills (knowing how to act / knowing how to be) in every geographic region of the country.

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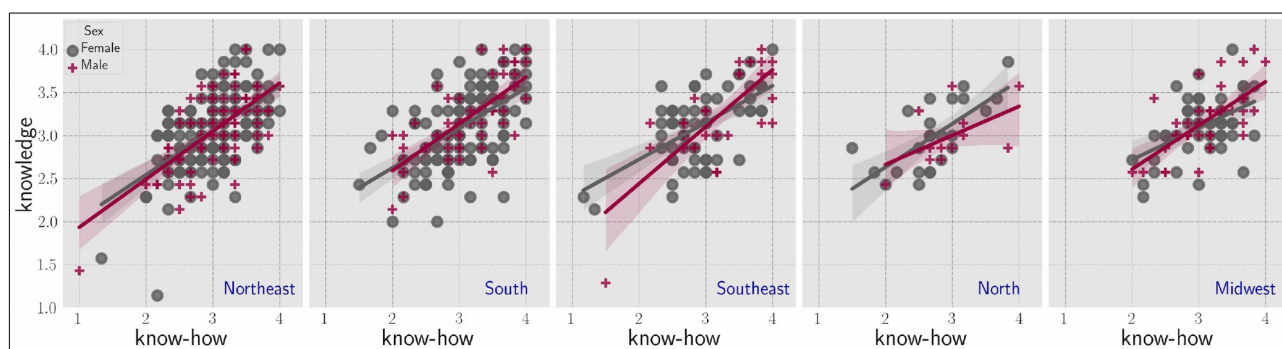
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(a)

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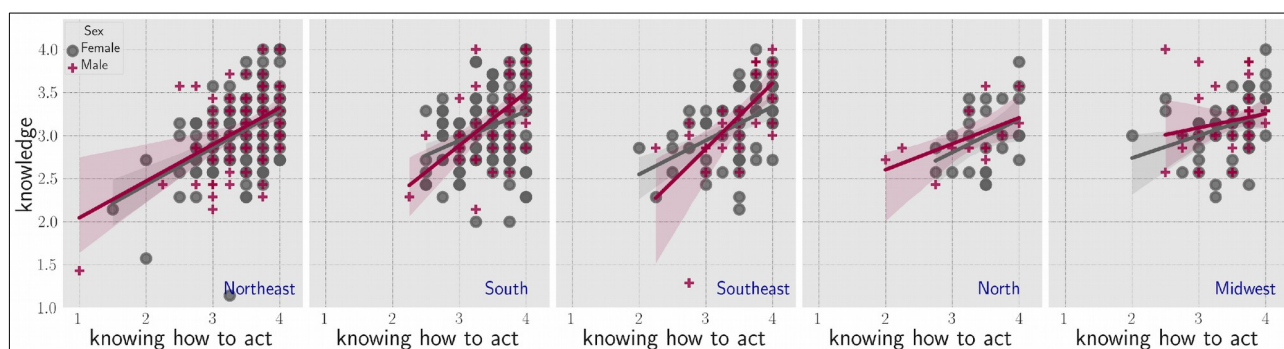
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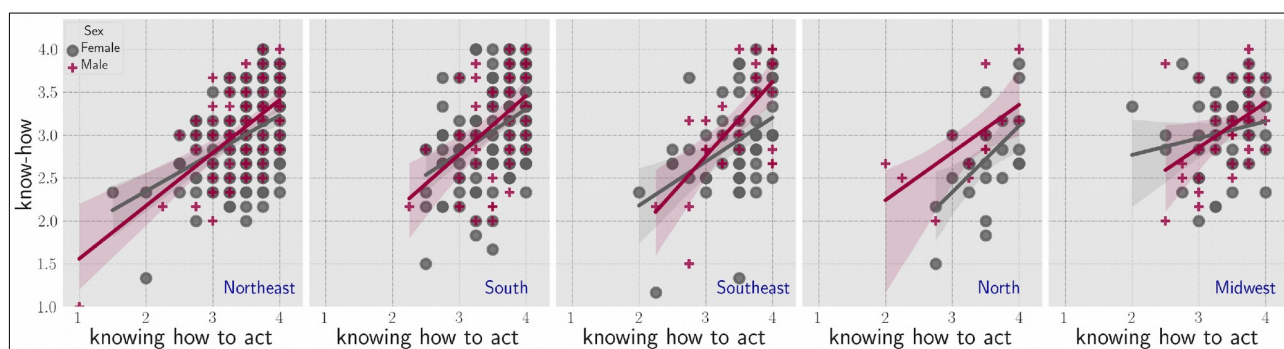
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Figure 2: Correlation between (a) factor 1 (knowledge) and factor 2 (know-how), (b) factor 1 (knowledge) and factor 3 (knowing how to act), (c) factor 2 (know-how) and factor 3 (knowing how to act) discriminated by sex and region.

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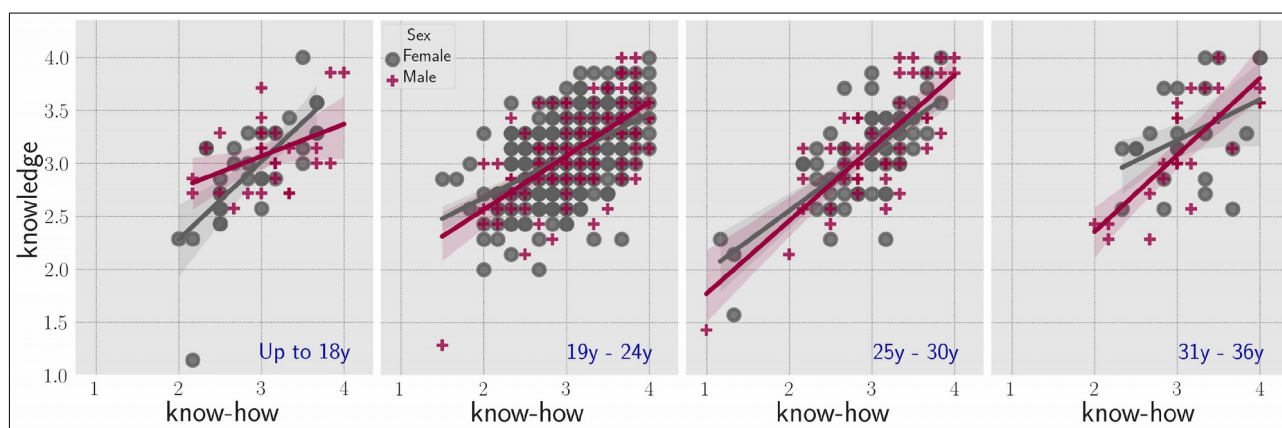
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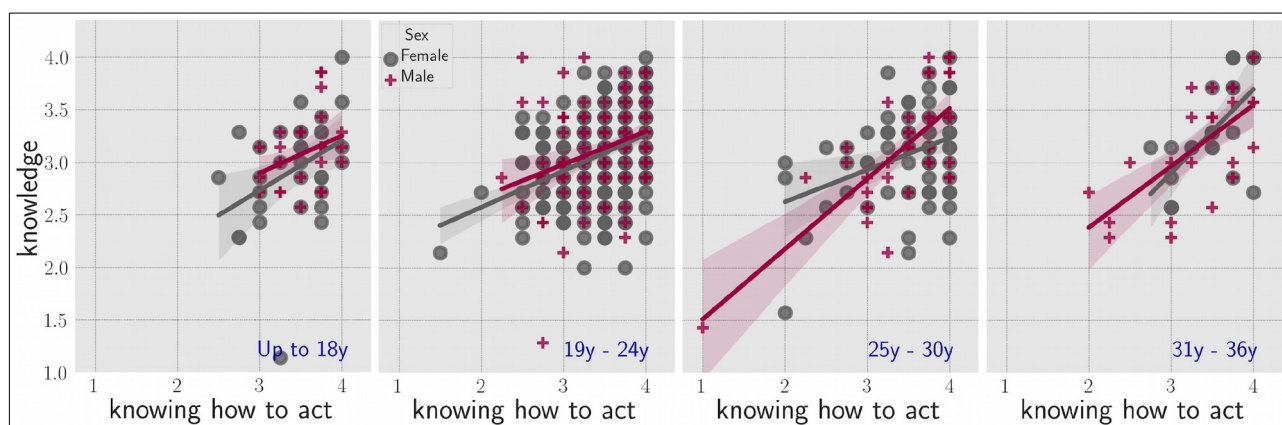
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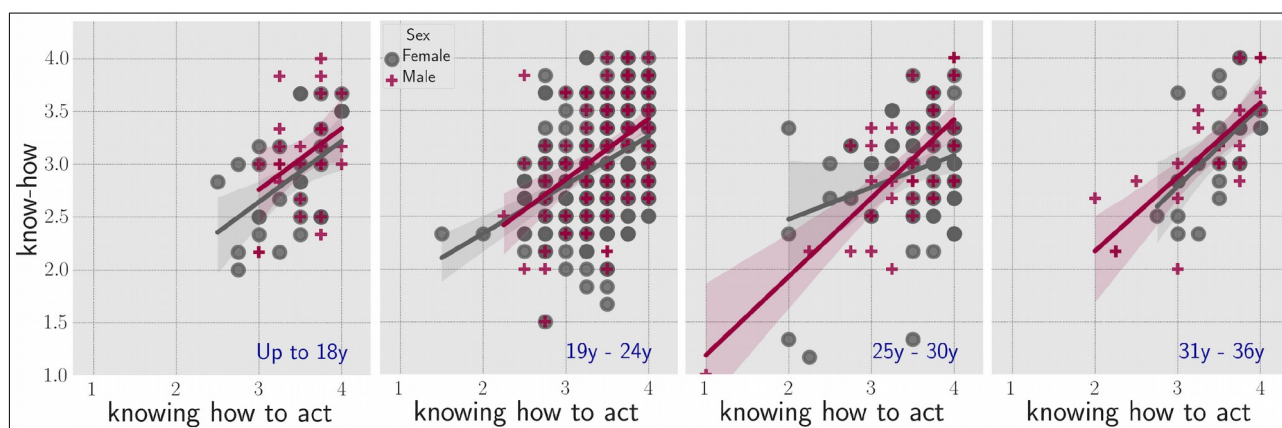
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Figure 3: Correlation between (a) factor 1 (knowledge) and factor 2 (know-how), (b) factor 1 (knowledge) and factor 3 (knowing how to act), (c) factor 2 (know-how) and factor 3 (knowing how to act) discriminated by sex and age.

Figure 3 shows the correlations between factors by gender and age. It is reputed that the difference between self-perception related to skills altogether with specific aspects (know-how) and technical skills (knowledge) is more evident in younger girls until 18 years old, when it is possible to recognize a positive difference concerning men. This indicates a possibility for changing the interpretation of social roles for women in the 21st century by the younger generations. The most

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prominent age group for men, in contrast with women, was between 31 and 36 years old. Perhaps this result may be related to motherhood, associated with the same age group for women. Regarding the correlation between factors 1 and 3, 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 factors 2 and 3, we realized that men and

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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 skills (knowing how to act / knowing how to be) during their career; in the contiguous age group (31 to 36 years), it returns to similarity.

## CONCLUSIONS

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The research reported in this work evidenced the self-perception of Brazilian chemistry students on the adopted dimensions regarding three factors: technical competences (knowledge), competences linked to specific aspects (know-how) and generic competences (knowing how to act / knowing how to be) in their careers. Reliability and validation measures were also provided for the questions composing the self-perceived skills of teachers in the initial chemistry training instrument.

Overall, the results demonstrated the presence of statistically significant differences in the self-perception of men and women about their own skills associated with knowledge construction in

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chemistry. When analyzing the correlations between average scores of the three factors while comparing the “region” categorical variable, we could see a larger discrepancy between the agreement obtained by men and women in the southeast and the north. Similarly, concerning age, the difference between their self-perception related to skills in their know-how and technical knowledge skills in relation to chemistry is more evident for younger girls under 18 years old. This result suggests the reasons for the absence of women in chemistry in high level positions.

Though we know that the instruments based on a Likert scale present contributions to studies on self-perceived competences, we alert that the results presented here have limitations. We

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adopted factors that are directly connected with discussions on the understanding of “competences,” which definition is present in exact sciences but might vary according to the field of study. Another aspect that we consider limiting in our research is allocated to the fact that we have a sample, albeit a significant one, that is not uniform in terms of participant distribution: women represented almost two thirds of respondents, and the southeastern Brazilian region (the most populated) did not present the largest number of respondents. The use of the SPCTICT instrument in other fields might need adaptation to incorporate the specificities of the different competences.

**AUTHOR CONTRIBUTIONS**

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

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**FIGURE CAPTIONS**

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Figure 1. Correlation between pair of factors discriminated by sex.

Figure 2: Correlation between (a) factor 1 (knowledge) and factor 2 (know-how), (b) factor 1 (knowledge) and factor 3 (knowing how to act), (c) factor 2 (know-how) and factor 3 (knowing how to act) discriminated by sex and region.

Figure 3: Correlation between (a) factor 1 (knowledge) and factor 2 (know-how), (b) factor 1 (knowledge) and factor 3 (knowing how to act), (c) factor 2 (know-how) and factor 3 (knowing how to act) discriminated by sex and age.

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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

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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.

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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.

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( ) 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

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#### 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



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**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

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**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.**

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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

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## 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.

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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.**

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( ) Strongly disagree

( ) Disagree

( ) Agree

( ) Strongly agree

## Appendix B - Likert Scale-based Instrument

(a) Women responses

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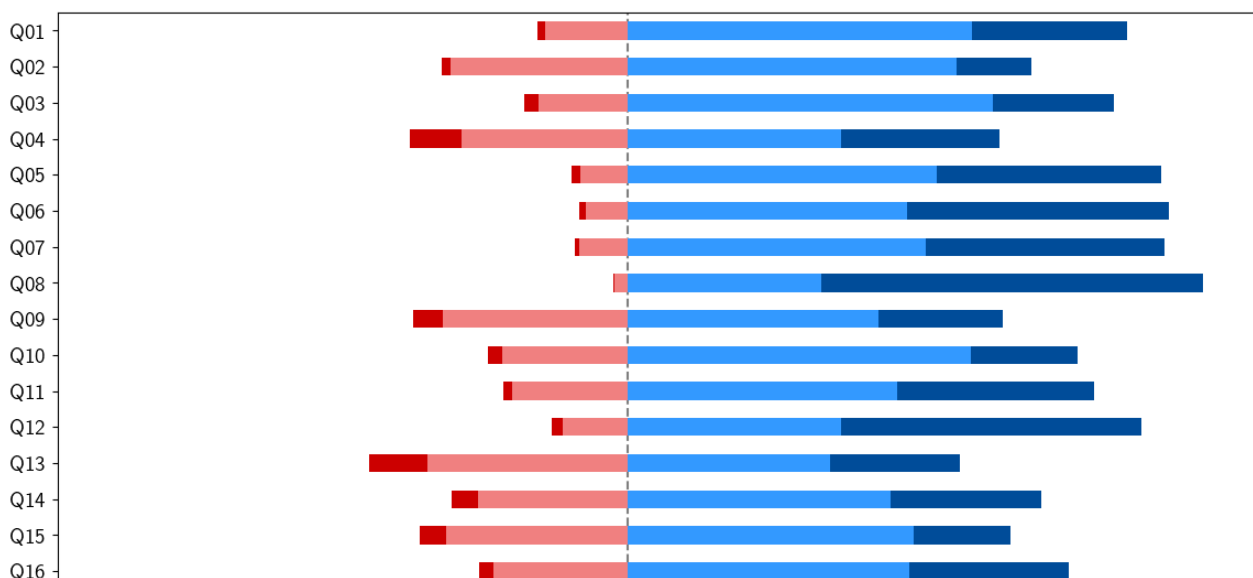
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(b) Men responses



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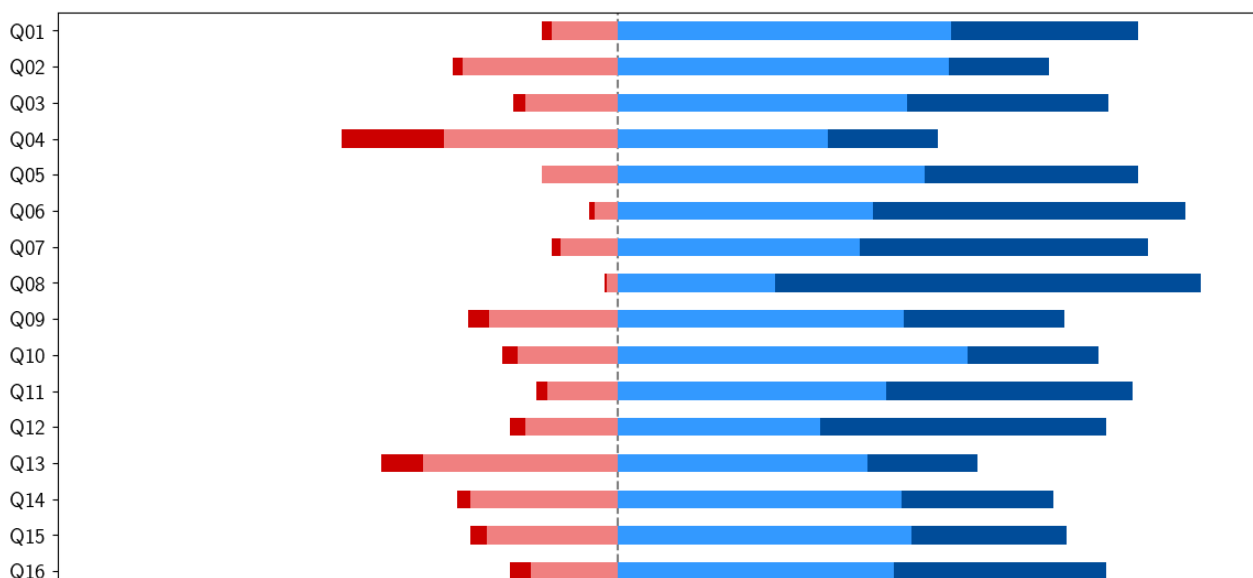
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**Appendix C - Heatmap for all 21 instrument items**

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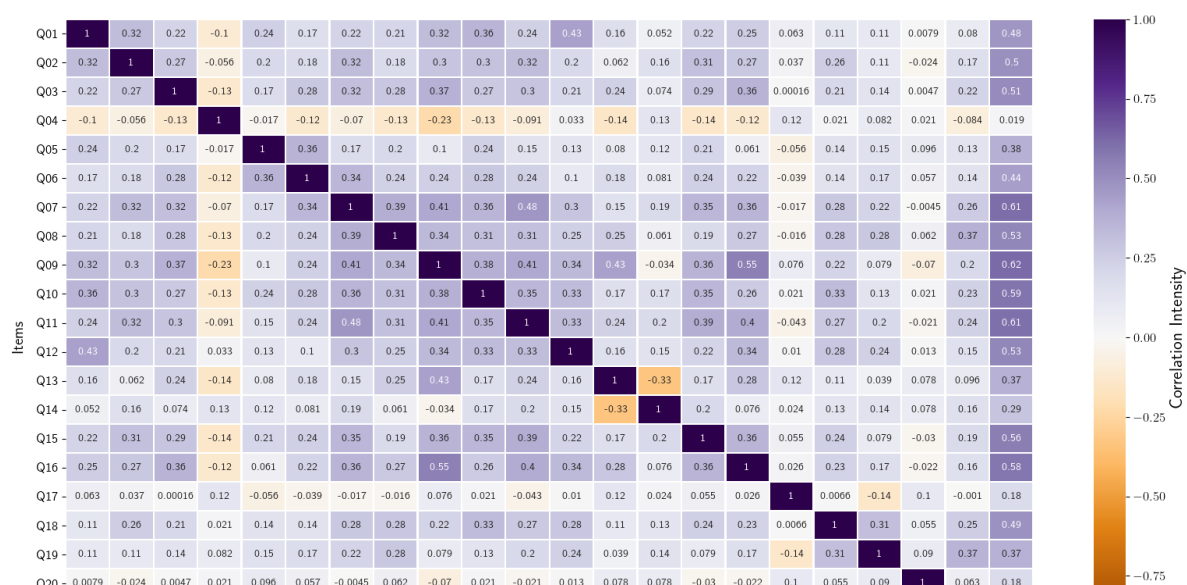
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