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ARTICLE

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CHEMISTRY SELF-CONCEPT OF HIGH SCHOOL STUDENTS INVESTIGATED BY THE PREPARATION AND VALIDATION OF A SCALE

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ABSTRACT:

In this study, we present the process of developing and validating a chemistry self-concept scale for Brazilian high school students and of evaluating the configuration of the sample's self-concept. We developed a structural model and a test that was applied to 203 students. The analysis was done using the item response theory and the classic test theory. The results indicated that the scale is valid and comprises three factors: performance, interest, and cognitive engagement. None of these factors prevail in the self-concept, which means that they all contribute equally to dimension this construct. Through this analysis, we also identified that only sex was a predictor. However, it only influenced the self-concept in the performance factor.

Keywords:
Chemistry Self-concept Scale, Instrument validation, Item Response Theory.

O AUTOCONCEITO EM QUÍMICA DE ESTUDANTES DO ENSINO MÉDIO INVESTIGADO PELA ELABORAÇÃO E VALIDAÇÃO DE UMA ESCALA

RESUMO:

Neste estudo apresentamos o processo de construção e validação de uma escala de autoconceito em Química para estudantes do ensino médio brasileiro e avaliação da configuração do autoconceito da amostra. Construímos um modelo estrutural e um teste que foi aplicado a 203 estudantes. As análises foram realizadas através do emprego da teoria de resposta ao item e da teoria clássica de testes. Os resultados indicaram que a escala é válida e é composta por três fatores: desempenho, interesse e engajamento cognitivo, sendo que nenhum deles prevalece no autoconceito, ou seja, todos esses fatores contribuem igualmente para dimensionar o constructo. Também por essa análise identificamos que somente o sexo foi preditor, contudo ele só influenciou o autoconceito no fator desempenho.

Palavra-chave:
Escala de autoconceito em Química; Validação de instrumento; Teoria de Resposta ao Item.

EL AUTOCONCEPTO EN QUÍMICA DE ESTUDIANTES DE LA ENSEÑANZA MEDIA INVESTIGADO POR LA ELABORACIÓN Y VALIDACIÓN DE UNA ESCALA

RESUMEN:

En este estudio presentamos el proceso de construcción y validación de una escala de autoconcepto en Química para estudiantes de la enseñanza media brasileña y la evaluación de la configuración del autoconpecto de la muestra. Construimos un modelo estructural y una prueba, que se aplicó a 203 estudiantes. Se utilizaron la teoría de respuesta al ítem y la teoría clásica de tests para realizar el análisis. Los resultados indicaron que la escala es válida y se

Palabras clave:
Escala del autoconcepto en Química; Validación de instrumento; Teoría de Respuesta al Ítem.

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compone de tres factores: desempeño, interés y compromiso cognitivo, pero ninguno de ellos prevalece en el autoconcepto, o sea, todos los factores contribuyen igualmente a dimensionar el constructo. Identificamos también por medio de ese análisis que solamente el sexo fue predictor, sin embargo influyó solamente en el autoconpecto en el factor desempeño.

INTRODUCTION

Self-concept can be understood as a construct of multiple dimensions related to how the individual perceives him or herself, referring to academic and non-academic questions (Bong & Clark, 1999; Silva & Vendramini, 2006). It constitutes itself as a personal agency mechanism that also influences people's performance. It can contribute to a broader understanding of how people develop attitudes towards themselves and how these attitudes affect their perspective on life (Silva & Vendramini, 2006).

Basically, self-concept can be taken as an organization of attitudes that are constituted by the subject's perception of his or her abilities and roles in the world; his or her social self, which reflects how this subject believes that others see and evaluate him or her, and his or her self, which highlights the type of person the subject would like to be (Wylie, 1974). Because it is a robust mental construction, psychologists have clearly outlined its relationship with student learning (Bauer, 2005).

The self-concept is constructed both by evaluations of people who are important to the individual (Bandura, 1986), in the social aspect and by the subject's comparisons (Pajares, 1996). These comparisons can be both internal, regarding the person's performance in related areas ("I am better in chemistry than in Portuguese"), and external, when the subject compares his or her performance with the others ("I am a better chemistry student than most of my friends") (Silva & Vendramini, 2006).

We can understand the self-concept as a specific belief of a person about their abilities, regardless of the domain. Concerning the academic domain, self-concept refers to the universe of representations that the student has of their abilities, achievements, and assessments of those same abilities and achievements (Silva & Vendramini, 2006).

Self-concept has also been identified as a contributing component in models of expectation of motivation and conceptual change. Motivation expectations are based on the notion that individuals will choose and will persist in doing a task if they have a reasonable expectation of success (Bauer, 2005). Nielsen and Yezierski (2015) point out that one of the most important characteristics of self-concept is perhaps its relationship with the cognitive domain.

Furthermore, experts indicate a close relationship between self-concept and academic performance (Wylie, 1974). This fact points to the need to consider the self-concept variable in research aimed at assessing academic performance in some area, since students build their judgments about their skills in a given domain, for example, in Chemistry, based on their achievements in this area (Nielsen & Yezierski, 2015).

In this perspective, accessing the students' chemistry self-concept can be a means to understand their performances in the face of this educational content. How a subject perceives his or her ability to learn the content can positively and negatively impact his or her relationship with that content and, consequently, impact his or her performance. The chemistry self-concept can be conceived as a generalization of the subject's confidence when exercising the student's role to learn the content, that is, his or her confidence to learn chemistry. This construct represents an organized system of beliefs that includes ideas about the content itself, which includes its importance in the subject's life, the modes of reasoning used, affective and behavioral relations with the content, among others. Authors point out that chemistry self-concept is related to students' success in this discipline and their ability to perform (Bauer, 2005; Lewis ***et. al.,*** 2009).

From the considerations of the research mentioned above, it is possible to perceive the importance that self-concept can have for students' success or failure in the face of educational content. The subjects' perception about themselves, which in the academic aspect is built during the schooling process, can be a watershed in future possibilities, such as career choices.

However, although there is a wide range of studies on the students' self-concept of all ages in the literature on educational psychology, the chemistry self-concept of high school students still needs attention (Nielsen & Yezierski, 2015). There is a chemistry self-concept inventory in the literature (Bauer, 2005) built from a self-description questionnaire to assess the affective component of university students' learning. This instrument contains several subscales (of academic performance, mathematics, etc.), but none about science. To address the content of Chemistry, Bauer (2005) reformulated the ten items of mathematics. Thus, the chemistry self-concept inventory consists of four scales, taken from the self-description questionnaire, and the ten items on chemistry.

Nielsen and Yezierski (2015) applied the chemistry self-concept inventory to 515 high school students divided into four different chemistry classrooms with different depth levels of study. They concluded that the inventory offered valid data on the self-concept of this sample. Although they do not make these students' nationality in their research explicit, everything indicates that the research was developed in North American schools.

In their bibliographic review, Gasparotto ***et. al.*** (2018) did not find any article within their search criteria that dealt with Brazilian high school students' self-concept. The authors systematically reviewed the research that analyzed the relationship between high school teenagers' self-concept and academic performance.

Given this gap in the national literature and the informative potential that a chemistry self-concept scale can offer, both for researchers and teachers, we seek to build a scale to access high school students' chemistry self-concept. We emphasize that, although designed for this level of education, the items can be easily adapted to access the trait at other levels, such as in elementary and higher education. In the next section, we describe how we built and validated our instrument.

METHOD

CONSTRUCTION OF THE SCALE AND SUBJECTS

For the construction of the chemistry self-concept scale, we adapted items from two self-concept scales already validated for their referred application contexts: the chemistry self-concept inventory (Bauer, 2005) used in the American context and a statistics self-concept scale for students Brazilians in this higher education course (Silva & Vendramini, 2006).

Bauer's chemistry self-concept inventory (2005) consists of 5 subscales: mathematics self-concept, chemistry self-concept (10 items), academic self-concept, academic satisfaction self-concept, and creativity self-concept, totalizing 38 items. For our instrument's construction, we used nine of the ten items related to the chemistry part. We discarded only one item that dealt with chemistry in other disciplines because it presupposes interdisciplinarity that is not recurrent in the Brazilian context. Our choice not to use the full chemistry self-concept inventory was based on the fact that the inventory is a very extensive instrument. In the text itself, it is recommended that the researcher use only the Chemistry items to reduce the application time. However, the author stresses the need for validation of this new instrument.

The self-concept scale in statistics (Silva & Vendramini, 2006) validated for university students consists of 21 statements. From it, we adapted items that we deem relevant to our object of study. These items dealt with the individual's perception of his or her performance, feelings about the content – if he or she considered it easy, interesting, etc., and his or her persistence to learn. We used twelve of its items. We discarded statements that established comparisons between student performance in the classroom and the course in question, comparing gender, age-range, and professional performance. Because we consider that they do not fit the context of high school, since in the regular course there are no great variations in the age range of students, neither the content of chemistry is addressed from the perspective of the performance of a profession.

Through the adaptations made from these two instruments, we built a scale composed of 21 statements, through which we seek to access the chemistry self-concept of high school students.

We use a Likert scale (1932) for the students' answers. This type of scale is suitable for instruments that access a particular latent trait on a scale that reflects that trait's gradation. Authors explain that the objective, in this case, is to verify how much of the trait is reinforced or is present in people's actions, behaviors, preferences, or attitudes (Amantes & Coelho, 2015; Pasquali, 1996). Thus, the statements that make up the scale seek to cover a range of endorsement degrees of the latent trait, in our case, the chemistry self-concept.

Latent variables or traits are attributes constructed from a theory but which are related to data also observable by theoretical parameters. The logic behind latent variable models is that differences in latent variables result in differences in observable variables (Golino & Gomes, 2015). In that way, the scale options indicated by the respondents in our instrument correspond to the observable data, and the chemistry self--concept is inferred from them.

Frame 1 presents the statements that make up our chemistry self-concept scale with the referred sources.

Frame 1. Statements of the scale of chemistry self-concept

	STATEMENTS	SOURCE
1	Being good in chemistry is important to me.	Adapted – S.S.C.S
2	I find it interesting to solve Chemistry problems	Adapted – S.S.C.S
3	In comparison to all students in my class, I am good at chemistry.	Adapted – S.S.C.S
4	Chemistry tasks are easy for me.	Adapted – S.S.C.S
5	I feel incapable in Chemistry class.	Adapted – S.S.C.S
6	I learn chemistry quickly.	Adapted – S.S.C.S
7	I usually do well in chemistry.	Adapted – S.S.C.S
8	I find Chemistry interesting.	Adapted – S.S.C.S
9	When a Chemistry exercise is difficult for me to solve, I try harder to solve it.	Adapted – S.S.C.S
10	I was never excited (studying or learning) with Chemistry.	Translated and adapted – C.S.C.I
11	I like to study chemistry when I'm not in class.	Adapted – S.S.C.S
12	Chemistry is "boring".	Adapted – S.S.C.S
13	I am good at understanding the ideas of Chemistry.	Translated and Adapted – C.S.C.I.
14	Chemistry as a subject intimidates me (makes me afraid).	Translated and Adapted – C.S.C.I
15	I would hesitate (think twice) to enroll in courses involving chemistry.	Translated and Adapted – C.S.C.I.
16	I generally do better on subjects or tasks that involve chemistry than other subjects and tasks that involve different content.	Translated and Adapted – C.S.C.I
17	I have a hard time understanding anything related to Chemistry.	Translated and Adapted – C.S.C.I

	STATEMENTS	SOURCE
18	When I think that the chemistry exercises are difficult, I usually give up doing them.	Adapted – S.S.C.S
19	I find the concepts of Chemistry interesting and challenging.	Translated – C.S.C.I
20	I usually have a hard time understanding topics that require knowledge of Chemistry.	Translated and Adapted – C.S.C.I
21	I confidently participate in discussions with friends at school on matters related to Chemistry.	Translated – C.S.C.I

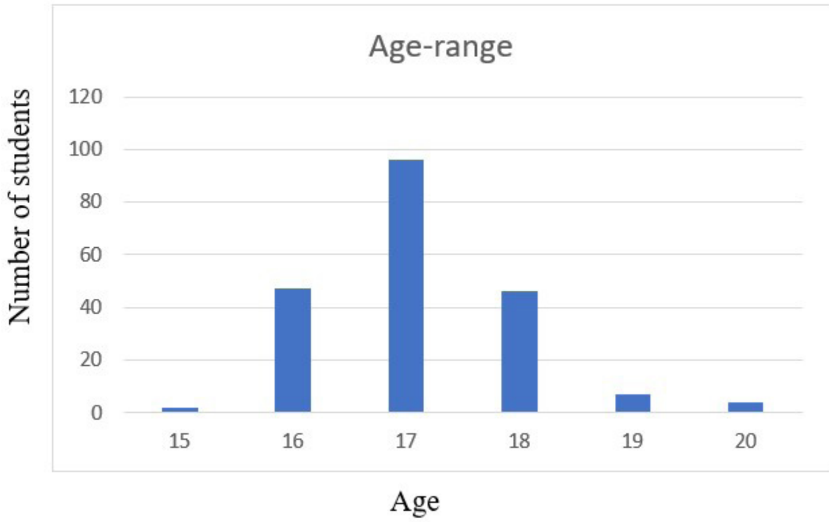
Legend:

S.S.C.S. = Statistics Self-Concept Scale

C.S.C.I. = Chemistry Self-Concept Inventory

Our research instrument was applied to 203 high school students from a state public school in Salvador, BA. These students were divided into 14 classes: six from the second year and eight from the third. Their ages ranged from 15 to 20 years old, of which 96 students (47.3%) were 17 years old. The majority of the sample (58%) consisted of female students.

Graph 1. **Age-range of the students**



Source: Research data.

We chose to apply our instrument to students of the second and third year of high school due to the longer time of contact with the discipline these students present than students of the first year. The data were collected in September and October 2018 with a collaborating teacher who teaches at the school.

ANALYSIS DESIGN

Of the 203 participants, we used 202 since one student left the test blank. We conducted two studies: i) evaluation of the validity of the constructed scale, how reliable and trustworthy its statements are to access the latent trait " chemistry self-concept " and, ii) analysis of the configuration of chemistry self-concept for the investigated sample.

The scale was validated using the R software (R Core Team, 2012), in which we evaluated the psychometric properties of the items and the model's adjustment by the theory. In this procedure, the following was evaluated:

i) the composition of the scale through exploratory factor analysis: in this type of analysis, the response matrix is used to identify patterns of grouping of items to assess the dimensionality of the test and reduce the number of factors that can explain such groupings. We conducted this analysis to verify a possible grouping structure of the responses independent of any ***a priori*** model.

ii) The best model's adjustment related to the Likert scale, using the ANOVA test (***Generalized Partial Credit Model***- GPCM, or the ***Samejima logistic model*** -Graded): the ANOVA test is used to compare models to show which one best explains the answer matrix. In other words, the indexes obtained with the test (A.I.C. and B.I.C.) evaluates which model is more suited to the empirical data. In our research, we tested two models, the GPCM and Graded, which are IRT models corresponding to how the scale is considered.

iii) the adjustment of the best model related to the number of parameters to be evaluated to explain the answer pattern, through the TLI, CFI, RMSEA, and cronbach's alpha indices: in the IRT there are different logistic models to estimate measures related to the latent trait of the people and measures related to the items. The Rasch model estimates the degree of difficulty of the item, or endorsement of the latent trait, as in the case of Likert scales; the two-parameter model considers the endorsement and its degree of discrimination (how much the item contributes estimating the latent variable and how much it can discriminate between high and low measures of the trait), and models that include the possibility of a random hit (for dichotomous items). All of them provide the subjects' measurements, which can be called skill, proficiency, latent trait. The TLI, CFI, RMSEA, and the cronbach's alpha indexes are evaluated for each of the models and based on the literature's criteria. The most appropriate is chosen: the Rasch model, the two-parameter model (2PL), or the three-parameter model (3PL).

iv) the adjustment of the items (using the MNSQ statistic): through this statistic, we evaluate the ***infit*** and the ***outfit*** of the items, which are parameters whose adequacy criteria are defined in the literature to identify items adjusted the response structure. Well-adjusted items have ***infit*** and ***outfit*** values between 0.5 and 1.5 (Linacre, 2010), items below or above these values contribute to degrading the measure; that is, they impair access to the trait in general.

The results of the analyses carried out using the methods described indicate the validity of the scale and the statistical model used to access the latent trait " chemistry self-concept." Thus, we proceed with analyses regarding the configuration of the chemistry self-concept of the sample. This second study was conducted by comparing the self-concept measures obtained using IRT, carried out using classical tests of mean difference (K-S test, T-test). We also evaluated possible predictors of self-concept: gender, year, and class; these analyses were made using the ANOVA test.

ANALYSIS AND RESULTS

STUDY 1 - VALIDATION OF THE SCALE

To validate our chemistry self-concept scale, we initially tabulated student responses on a double--entry table. The applied questionnaire used a Likert scale (1932), in which students indicate the degree of agreement with the presented statements. The Likert scale has five response options: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. For data processing purposes, we assigned values from 1 to 5, for each of the answer options, 1 for Strongly Disagree, and so on. In our scale, such as in the self-concept scale in statistics (Silva & Vendramini, 2006), there were inverted statements. In these items, our attribution of values has also been reversed, being 5 for Strongly Disagree.

We used Software R (R Core Team, 2012) to carry out exploratory factor analysis. This type of analysis is recommended for situations in which one does not start from a theory to infer groupings of items in factors. We used the parallel analysis method, which consists of generating an aleatory random sample and comparing the autovalues of the empirical sample with the autovalues of this aleatory random sample (Hayton, Allen & Scarpello, 2004). This analysis's output presents an indication of components and factors that must be considered for the empirical input data and a graph in which the autovalues of the main components and the factorial are plotted. The result indicates that the elaborated scale is composed of three factors and two components. The interpretation of factors and components varies in the literature. In general, they justify the separation of the instrument into subscales that access a general latent trait or to establish different dimensions related to different traits that may or may not compose a general component. The choice for interpretation depends on the study's several characteristics, with the objective and theoretical perspective being the most common parameters for interpreting these results. In our study, we considered the factors as subscales or facets of the latent self-concept trait since we understand it as a general attribute of the subject.

From the Factor Analysis, we identified the grouping of items in the three factors indicated for parallel analysis. We found that the first facet consists of twelve items (statements 3, 4, 5, 6, 7, 13, 14, 15, 16, 17, 20, and 21), the second of seven (statements 1, 2, 8, 10, 11, 12 and 19) and the third of two (statements 9 and 18).

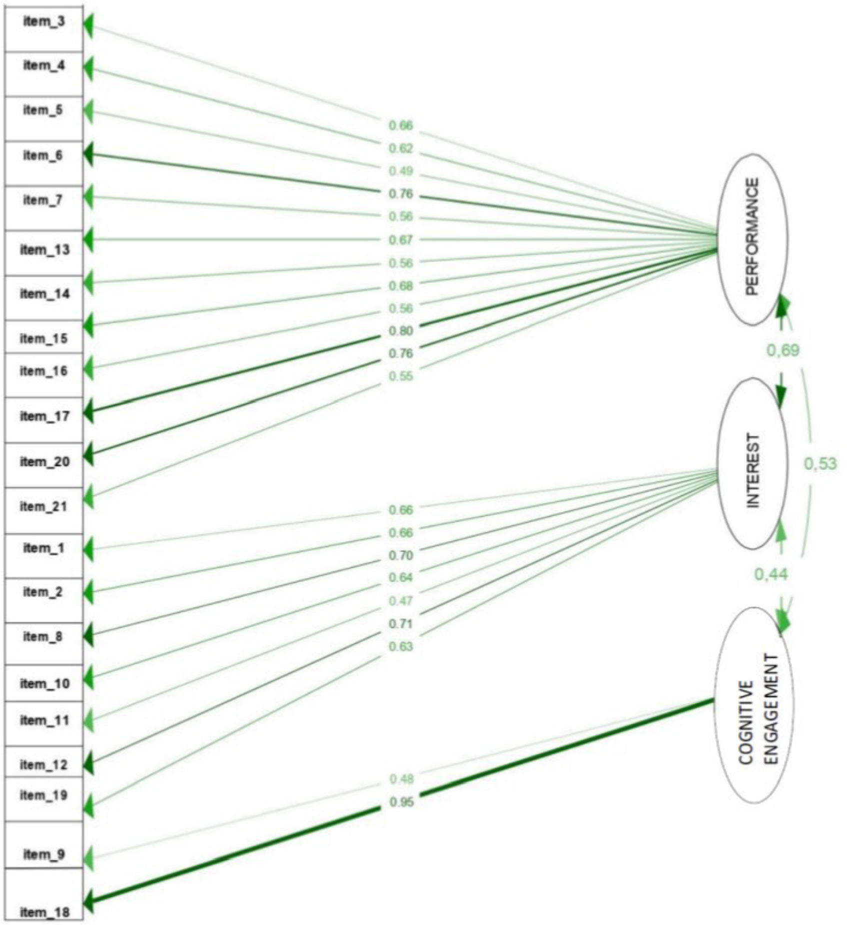
Qualitatively analyzing the statements that make up each facet, we classify the first as performance, the second as interest, and the third as cognitive engagement. In the facet classified as performance, we have statements that refer to the student's personal perception of how well they perform tasks or experiences situations related to Chemistry's content. For example, the statement "I learn Chemistry quickly" (item 6), the statement "I have difficulty understanding anything related to Chemistry" (item 17) (at the time of tabulation of the data, inverted statements like this are tabulated in reverse, which, for qualitative interpretation, leads to an inversion of its meaning).

The facet that corresponds to the interest is composed of statements that demonstrate a personal perception of the subject's intrinsic motivation (Ryan & Deci, 2000). How he or she perceives his or her motivation to learn Chemistry, constituting a genuine interest in the content beyond the school situation. As examples, we have the statements "I find Chemistry interesting" (item 8) and the statement "I find the concepts of Chemistry interesting and challenging" (item 19).

The facet classified as cognitive engagement (Fredricks, Blumenfeld & Paris, 2004) concerns statements that refer to the subject's personal perception of the effort he or she put into learning the content. For example, the statement "When a Chemistry exercise is difficult for me to solve, I try harder to solve it" (item 9).

As a result of the evaluation of the scale as a theoretical model of the investigated latent trait, we obtained a structure, represented by figure 1, which determines what each item accesses in terms of the three facets of the self-concept: 1 - performance, 2 - interest and 3 - cognitive engagement. The structure shown in figure 1 concerns a structural model (Borsboom, 2008), in which there is the contribution value of each item to dimension each facet. This means that item 17 dimensions the performance facet better than item 5, just as item 12 contributes more to dimensioning the interest facet than item 11, and item 18 contributes more to dimensioning the facet of cognitive engagement than item 9.

Figure 1. Grouping of the items in the factors



Source: Research data.

Having stipulated the theoretical model for interpreting the self-concept trait in Chemistry, we proceed with the validation by comparing models concerning the scale. We tested two models: 1) Generalized Partial Credit Model (GPCM), 2) Samejima logistic model (Graded). In applying the IRT for Likert-type scales, these models are frequently used, and the choice is made according to the adequacy of the data to the model. The relationship between the answers given on the Likert scale with the *theta*, an unobservable underlying measure associated with the chemistry self-concept, is established through these models. It is assumed that each increasing value of the scale indicates a cumulative step towards higher values in the latent variable (Nunes, *et. al.,* 2008).

The basic difference between the models is that for graduated scales (Samejima logistic model), it is assumed that the advances in Likert scores are constant and equal for all items. In the partial credit model (Generalized Partial Credit Model), this condition is relaxed, allowing for different distances between the Likert scores, depending on the item to be considered (Nunes, *et. al.,* 2008).

We tested the fit of the two models using ANOVA in the R program, evaluating the Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) indexes in the paired comparisons. According to the literature, the lowest AIC and BIC rates model is considered the best model (Finch & French, 2015; Golino & Gomes, 2015), having a significant difference between them.[1] Table 1 presents the comparison between the Generalized Partial Credit Model and the Samejima logistic model. We verified that the second model presents a better fit (AIC_{GPCM} = 10753,53; AIC_{Graded} = 10651,57, $p < 0,05$).

Table 1. Comparison between the models

	AIC	AICc	SABIC	HQ	BIC	logLik	X2	df	p
GPCM X Graded	10753.53	11486.16	10773.70	10946.28	11229.92	-5232.765			
	10651.57	11384.20	10671.74	10844.32	11127.96	-5181.784	101.962	0	0

Source: Research data.

Once the model was defined by the ANOVA test (the Graded), we evaluated its adjustment and discrepancy indexes. We found that the indexes demonstrate excellent adequacy (TLI = 0,9937, CFI = 0,9962 and RMSEA = 0,0122.) The TLI (Tucker Lewis Index) and CFI (Comparative Fit Index) calculate the model fit; values higher than 0.95 indicate excellent adjustment, and those above 0,90 indicate adequate adjustment (Bentler, 1990; Hu & Bentler, 1999). In turn, the RMSEA (Root-Mean-Square Error of Approximation) is a measure of discrepancy, with results expected to be less than 0,05 (Finch & French, 2015; Golino & Gomes, 2015).

We also evaluated the reliability of this model using Cronbach's alpha. It is documented in the literature (Kline, 1993; Martins, 2006; Nunnally, 1978) that the measurements are reliable when this coefficient is above 0,7. Our scale showed Cronbach's alpha equal to 0,89, indicating high reliability.

Once we stipulated the model and verified its accuracy, we calculated the items' parameters. In the Item Response Theory (IRT), parameter a1 refers to the items' ability to discriminate, that is, the extent to which an item can differentiate people with higher and lower measures corresponding to the latent trait in terms of the marking of answers; the d to the difficulty of transition from one class to another, that is, the measure corresponds to the trait of the subject who can mark both one category (as I agree) and the following (strongly agree), with an equal chance. This shows the threshold of change that characterizes the latent trait in question. For people with traits smaller than a certain value that represents the transition between categories, there will be more chance of endorsing the alternative less (in the example, mark I agree). In contrast, those with a greater trait than the transition value tend to endorse more (in the example, mark strongly agree). These results provide us with parameters to assess how positive the subjects' endorsement concerns the investigated trait. In our case, chemistry self-concept.

As our model consists of three facets, we can discriminate each of them (a1 the item's discrimination ability in the performance facet, a2 item's discrimination ability in the interest facet, and a3 item's discrimination ability in the facet of cognitive engagement). We use these measures to ascertain any inconsistencies in the items (such as the failure to maintain the hierarchy of categories and items with inverted discrimination). Also, evaluating the characteristics of the items, we used a hypothesis test carried out by the item fit command of the R program, which provides the significance level p.S_X2 to ascertain each item's suitability to the tested model. The null hypothesis of the test is that the item is adequate, in which case the value of p.S_X2 must be bigger than 0.05 for a good fit.

Table 2. Parameters of the items

Item	*a1*	*a2*	*a3*	*d1*	*d2*	*d3*	*d4*	*p.S_X2*
1	-1.461	0.699	0.071	4.035	2.040	0.829	-2.335	0.369
2	-1.635	0.587	-0.061	4.050	1.532	1.025	-3.237	0.360
3	-1.531	-0.895	-0.175	2.602	0.472	-1.547	-4.344	0.225
4	-1.459	-0.478	-0.363	3.537	0.730	-0.572	-4.902	0.634
5	-0.949	-1.051	0.540	3.264	1.733	0.692	-1.604	0.586
6	-1.917	-1.409	-0.466	2.839	0.324	-0.648	-5.027	0.168
7	-1.228	-0.742	-0.390	3.270	1.162	0.042	-3.262	0.214
8	-2.080	1.484	0.328	4.635	2.813	1.546	-2.332	0.457
9	-0.643	-0.080	0.946	3.324	1.315	0.642	-2.366	0.054
10	-1.135	0.380	0.161	2.572	0.903	0.345	-1.876	0.037
11	-0.812	0.468	0.264	1.438	-0.694	-1.349	-3.112	0.686
12	-1.592	0.837	0.301	4.192	1.952	0.599	-1.758	0.148
13	-1.576	-0.328	-0.116	3.424	1.209	-0.097	-3.647	0.566
14	-1.128	-0.594	-0.022	2.253	0.985	0.267	-1.699	0.021
15	-1.380	0.025	-0.202	1.010	-0.419	-1.143	-2.838	0.328
16	-1.354	-0.329	-0.209	0.966	-0.974	-2.313	-4.054	0.698
17	-2.335	-1.051	0.568	4.713	2.122	0.760	-3.578	0.429
18	-2.028	-1.751	4.004	8.265	2.577	1.285	-5.559	0.126
19	-1.312	0.657	-0.161	3.939	2.355	1.179	-2.313	0.499
20	-2.302	-1.019	0.000	3.820	0.914	-0.544	-4.395	0.240
21	-1.271	0.000	0.000	1.184	-0.011	-1.208	-3.197	0.496

Source: Research data.

Of all our items, only 10 and 14 had a p.S_X2 value smaller than 0,05; that is, they were the only ones with a bad adjustment. This result showed problems with the referred items. About item 10, we consider that the value of its index is due to the high degree of commitment that the statement presented in the item imposes - "I was never excited (studying or learning) with Chemistry." Thus, we decided to change "was never" to the expression "don't get", which imposes a lower degree of commitment for future versions of the instrument.

As for item 14, the statement contained in this item is as follows - "The Chemistry subject intimidates me (makes me afraid)". We believe that the bad adjustment may be because students are not necessarily afraid of the subject but rather feel insecure. There may have been a dubious interpretation because the expression in parentheses made the statement more verbose. As we have no way of exactly identifying the cause of the bad adjustment, since the two assumptions are equally plausible and difficult to circumvent in a reformulation, we chose to remove the explanatory parenthesis and keep the item future versions.

Concerning the ability to discriminate in the facets, concerning performance, the items that most discriminate the subjects are number 17 and 20, about interest, the item with the greatest ability for discrimination is 8, and regarding cognitive engagement, the item that most discriminates is item 18. The item's ability to discriminate relates to how well it separates individuals with a lower and higher value from the latent trait.

After conducting the analyzes above, factor analysis, ANOVA test, reliability analysis, and the parameters of the items, we had as a result of the composition of a valid scale to access the chemistry self-concept with the grouping of the scale items in three facets that dimension the trait (performance, interest and cognitive engagement). This means that we have an instrument that is theoretically defined in terms of Chemistry Self-concept and empirically validated since the answers were adjusted to a structured model for the study of that trait. These facets, which we consider as components of the chemistry self-concept latent trait, allow us to evaluate how this trait is configured in a sample of subjects, and from the modeling, we obtained measures through which we can investigate what can influence it. This study is presented below.

STUDY 2 - ANALYSIS OF THE CHEMISTRY SELF-CONCEPT OF THE SAMPLE

To carry out the study on our sample's chemistry self-concept, we used the SPSS software (IBM_CORP, 2011). Initially, we tested whether the subjects equally endorse the performance, interest, and cognitive engagement facets or whether one of them stands out about the others when we evaluate the chemistry self-concept.

The data to be compared here refer to the measures estimated for people's "proficiency", through IRT. This proficiency is interpreted as the measure of self-concept, which, in our case, consists of values in 3 facets. In this way, we have a measure for self-concept on the performance side, another measure of the attribute on the interest side, and one more on the cognitive engagement side. To identify whether one of these facets is more endorsed than another, we assessed whether the means of these measures are statistically different.

We started with some tests on the sample distribution to ensure the proper use of mean-difference tests. One of the sample distribution tests is the normality test, which was assessed by Kolmogorov-Smirnov. It indicates whether or not the measure we are working with is normally distributed, which can be an important criterion for comparing measures depending on the subsequent method. In our case, the measurements of people obtained in the IRT analysis refer to an interval measurement,[2] thus allowing for tests of mean differences and regression tests (Triola, 2005). The result indicates that the distribution is normal in all factors ($KSF1= 0{,}031$ $pF1 = 0{,}20$; $KSF2=0{,}054$, $pF2=0{,}20$; $KSF3=0{,}074$, $pF3= 0{,}09$).

To verify the existence or not of an endorsement difference, we performed a paired sample T-Test comparing the self-concept means in each facet. For factor 1 (performance) the mean was -0,066 ($SD = 1{,}413$); for factor 2 (interest) the mean was 0,053 ($SD = 1{,}306$); for factor 3 (cognitive engagement) the mean was 0,013 ($SD = 1{,}418$). As a result, there is no endorsement difference in any of the three factors for the measure of chemistry self-concept since the comparisons show a $p> 0{,}05$. This index is reported for evaluating the hypothesis test; the null hypothesis is that the means are equal. As the p-value was greater than the 0,05 alpha significance level, we accept this hypothesis, meaning that the facet means are not statistically different.

Table 3. Result of the T-Test

Factors		Mean Standard	Deviation	t	p
Performance	Interest Cognitive Eng	-0,066	1,413		
				0,673	0,502
				0,493	0,622
Interest	Performance Cognitive Eng.	0,053	1,306		
				0,673	0,502
				0,434	0,665
Cognitive Engagement	Performance Interest	0,013	1,418		
				0,493	0,622
				0,434	0,665

Source: Research data.

Next, we evaluate whether there is any predictor, something that can influence the endorsement of chemistry self-concept factors. This means investigating whether any characteristics, contextual or individual, influence how subjects endorse each of the three facets of self-concept. For this, we tested whether the three factors are equally endorsed regardless of the class, sex, and year of the respondents. Ascertaining whether these variables influence the factors that make up the self-concept is important to highlight aspects related to students' performance in chemistry, such as the studied content, the context of the classroom, gender roles, etc. We could not evaluate other possible predictors, such as the school effect, the teacher effect, the social context, the economic context, etc., because we do not have data on these variables. We recognize that many can be predictors of this construct. Information of this nature can reveal variables that influence students' academic performance beyond the classroom and the school itself.

For the analysis of the predictors, we used the ANOVA test again, which, instead of comparing groups in terms of adjustment (as done in the previous section), compares whether the population mean of two groups is statistically different the hypothesis test. The null hypothesis is that the means are equal; that is, there are no significant differences between the factors that make up the chemistry self-concept of the groups tested. The results are shown in table 4.

Table 4. Results of the ANOVA test

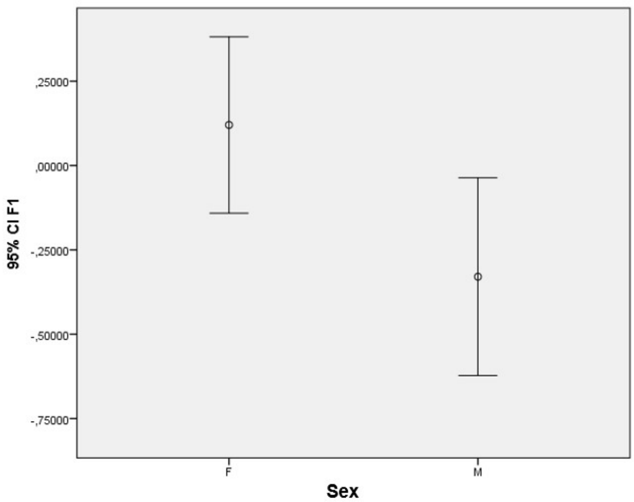
		PERFORMANCE				INTEREST				COGNITIVE ENGAGEMENT			
		F	**p**	**Mean**	**SD**	**F**	**p**	**Mean**	**SD**	**F**	**p**	**Mean**	**SD**
Sex	Fem.	5,225	0,023	0,129	1,437	0,969	0,326	-0,022	1,334	0	0,998	0,019	1,180
	Mas.			-0,329	1,350			0,162	1,266			0,019	1,112
Year	2nd year	0,955	0,330	-0,173	1,393	2,185	0,141	-0,095	1,341	1,876	0,172	0,135	1,107
	3rd year			0,022	1,431			0,177	1,269			-0,087	1,178
Class	M2	1,089	0,371	-1,322	2,812	1,195	0,286	1,074	2,618	1,323	0,202	1,185	1,264
	M3			-0,292	1,319			0,435	1,194			0,082	0,859
	M4			0,905	-			0,885	-			1,056	-
	M5			-0,022	1,950			0,327	1,800			-0,226	1,422
	M6			0,429	1,075			0,196	0,972			0,014	1,165
	M9			0,258	1,235			-0,245	1,217			-0,516	1,165
	M11			0,014	1,689			-0,110	1,576			0,103	1,068
	M13			0,203	1,270			-0,680	1,129			-0,340	1,523
	M14			-0,105	0,982			-0,284	1,045			0,251	0,847
	M15			-0,649	1,395			0,322	1,315			0,222	1,242
	M16			-1,499	1,125			1,100	0,643			1,117	1,447
	M17			0,534	1,510			0,039	2,377			-0,485	0,684

Source: Research data.

From the table, we found that no p-value was less than 0,05, except for the sex predictor in the performance facet. For this predictor, the p-value is below 0,05, which implies refuting the null hypothesis of equality of the boys' and girls' means at the 95% significance level. This means that there is a difference in the endorsement of the performance factor depending on the respondent's sex, but there is no difference for any other factor and category, since in all other cases, the null hypothesis of equality of means was accepted (p> 0,05).

Our sample, composed of 118 female students and 84 male students, presented a mean self-concept in the performance factor for the first ones of 0.129 (SD = 1.437), and for the second, a mean of -0.329 (SD = 1.350). These means can be seen in Graph 2, which presents the two categories on the x-axis (female and male) and on the y-axis the mean of the latent trait in that facet, represented by mark of the median error bar. The graph shows the difference in endorsement to the trait depending on the respondent's sex.

Graph 2. Relation of the factor performance with the variable sex



Source: Research data.

Regarding the other tested predictors: year and class, ANOVA's hypothesis test did not show any significant difference between the groups. This means that the fact that the student is in the second or third year does not interfere with his or her perception in any of the facets of the self-concept. One hypothesis is that self-concept, as well as an attitude towards science (Silva, 2015), is configured as a trait whose change requires a long time, and the difference in series may not capture such a change. Regarding the class predictor, the fact that there is no endorsement difference for the three facets may be related to the instruction context: for this particular predictor, many variables must be evaluated in the interpretation (such as teacher effect, type of instruction, the context of education, class, personal history, socio-cultural profile, etc.), so further study is needed to build more compelling evidence.

DISCUSSION OF RESULTS

As a result of our first study, we found that the scale built to access the latent trait chemistry self-concept is composed of three factors or facets: performance, interest, and cognitive engagement. We can interpret the high correlations found between the three facets as an indication that the set of items dimension a single construct, in this case, the chemistry self-concept. The greatest correlation is between performance and interest (0.69), indicating that the student's perception of his performance is closely related to his intrinsic motivation. This result is reasonable when we consider that the intrinsically motivated subject invests effort into achieving high performance, which influences its own perception of its performance in the area. We think that, in terms of hypothesis, there may be feedback in this sense: self-perception of performance can influence intrinsic motivation positively or negatively. This certainly interferes in different domains, from professional choice to reactive behavior towards certain disciplines' contents. In other words, the subject who perceives itself with high performance in a given content will tend to develop greater interest in that content and related contents, determining his or her school trajectory and, most likely, his or her professional trajectory.

The importance of intrinsic motivation for self-concept and as a mediator in the achievement of competence is documented in the literature (White, 1959). This type of motivation comes from a genuine interest in the object and is an important mediator of engagement in school achievements, contributing to potentialize the learning process. In other words, this is the most desirable type of interest for teaching and learning situations; for students to be interested in the knowledge itself. However, extrinsic motivation, such as passing exams and obtaining grades, is also a factor that contributes to learning (Amantes, 2009).

The smallest correlation is between the facet of interest and cognitive engagement (0.44); that is, the subject's perception of his effort to learn Chemistry is related to his or her intrinsic motivation on a smaller scale. This result can be interpreted using extrinsic motivation as a parameter. One hypothesis is that cognitive effort is influenced more by external factors, such as grade acquisition, such as by endogenous factors related to personal interest. As an implication, we can emphasize the importance of extrinsically motivating students to get involved (Amantes, 2009) beyond behavioral engagement, with an investment for deeper understanding, even if the content does not intrinsically motivate them. In the school context, it is practically impossible, given the heterogeneity of the environment, that the whole set of students in the same classroom share the same intrinsic interests. But they certainly have some learning or performance goals in common. The teacher can take advantage of this so that an environment of high cognitive engagement is created intrinsically motivated to achieve these goals.

We also pointed out that it would be interesting that the student went from an extrinsic to intrinsic motivation during the teaching and learning process. This change has a double effect: by increasing its intrinsic motivation, the student tends to improve their perception of their performance since the two facets are strongly related. Having a better perception of their abilities, the student will tend to persist in the tasks since it expects success (Bauer, 2005). Its persistence improves its performance, thus creating a cycle. The question that arises is how to promote the transition from one motivation to another and the consequent improvement in students' self-concept. In this sense, we consider that the scale validated here constitutes a potential instrument to assess the students' perception. Once one possesses this information, it is possible to develop strategies and monitor their effects.

In our second study, in which we investigated the configuration of high school students' chemistry self-concept, we first analyzed whether there was a difference in endorsement depending on the factor. The T-test indicated that the endorsement is the same for all facets; that is, none of them has been more strongly endorsed than the others. This means that the subjects' perception of their performance is not more positive than that of interest or cognitive engagement.

Our self-concept measurement scale ranges from -5 to 5 logits,[3] the result of the mean of the facets indicates that the self-concept of the students in our sample is not very positive nor negative, (Performance - the mean was -0.066 (SD = 1.413), Interest - the mean was 0.053 (SD = 1.306), and Cognitive Engagement - the mean was 0.013 (SD = 1.418)). However, there seems to be a negative trend for the performance aspect, which is an indication to be studied in more detail in research with a larger sample. In this sense, our results point to future relevant research questions, fulfilling their role as an exploratory study.

Then we evaluated what could influence each facet's endorsement of the self-concept; in this case, the guiding question was: does the fact of being, for example, male changes the way the subject perceives his performance? For this analysis, we found that only one of the predictors had an influence (sex) on performance, with girls showing greater endorsement. In other words, the girls had a higher perception of their performance in chemistry than the boys (the mean for the girls was 0.129 (SD = 1.437, and for the boys, it was equal to -0.329 (SD = 1.350)). However, they did not present difference in perception regarding interest or cognitive engagement.

The relationship between the sex predictor and attitude towards science is documented in the literature. One of the most consolidated results in science education research is that school science, as it is routinely taught, causes boys to have more positive attitudes than girls (Weinburgh, 1995). It is worth mentioning that according to the literature, the differences between men and women concerning science and scientific education are not sex heritage but are produced and reproduced in social relationships (Lima Júnior, ***et. al.,*** 2011).

We consider that, to some extent, the attitude towards science is related to the facet of interest of our chemistry self-concept scale. However, our results contradict what is usually pointed out since there was no difference in the endorsement of interest in the sex predictor, this being only for performance. This result brings two pertinent questions to be discussed and researched in the area: i) to what extent are interest and performance configured as distinct constructs, and how can they be interpreted in the current set to assess differences about sex? Much has been discussed about changes in access to scientific knowledge, both from the perspective of the school approach and the perspective of scientific culture, formerly well directed towards so-called masculine "interests" (Rosa, 2018). The popularization movements of Science, Science and Daily Life, STSE, among others, somehow break with this culture and consequently bring other discussions about belonging to a certain group for the learning of sciences. In this sense, another question that also becomes relevant is: ii) concerning scientific preferences, what has changed in boys and girls? Our results demonstrate that further studies are needed in this regard.

FINAL CONSIDERATIONS

This article presents the validation process of a chemistry self-concept scale for high school students from Brazilian schools. The instrument was adapted from a chemistry self-concept inventory and a statistics self-concept scale. As a result of our work, we have a validated chemistry self-concept scale with the modification of items 10 and 14. We obtained good adjustments of the items concerning the itemfit index. The test's internal consistency was analyzed employing Cronbach's alpha index, the composition of the scale by parallel analysis, and the groupings of items in each facet by factor analysis.

Regarding the degree of discrimination, the items that discriminate most refer to the statements: "I have difficulty understanding anything related to Chemistry" and "I usually have difficulty understanding topics that require knowledge of Chemistry" (in the performance aspect)), the statement "I find Chemistry interesting" (in the facet of interest), and concerning cognitive engagement the statement that most discriminates is "When I think that the Chemistry exercises are difficult, I usually give up".

Regarding the facets of the studied population's self-concept, we identified no difference about the degree of endorsement between them. Regarding the tested predictors, we identified a difference in endorsement only in the performance factor for the gender predictor; the other predictors - year and class, did not show any difference in endorsement in any factor. From this result, we conclude that our chemistry self-concept scale can be applied to different high school years without the need for distinctions.

Our results indicate that sex is a predictor of the performance facet of chemistry self-concept, which should be evaluated in future research with larger samples. We consider that, due to the research notes that deal with gender issues and interest in science, the relationship between the facets of self-concept and gender should be analyzed in more detail, and, in this sense, the scale should be validated for being widely used.

We believe that this instrument has many potentials to help researchers and teachers to, beyond the possible predictors of chemistry self-concept, understand the relationships between self-concept and academic performance in that component. Instruments like this have already been used in other countries (Bauer, 2005) and the results are not consensual.

Also, the self-concept scale can be used in different perspectives:

i) from the teacher's point of view: having access to the students' self-concept can help the teacher to develop teaching strategies that motivate students more, that increase engagement, and that contribute to change the negative self-concept;

ii) from an academic point of view: the self-concept scale can help to investigate issues that are related to the most diverse areas of teaching and learning, such as, for example, ascertaining the relationship between self-concept and learning, self-concept and attitude, teaching methodologies and self-concept of students, whether certain methodologies favor self-concept or not, the association of teaching methodologies to increase self-concept, etc.;

iii) From a research point of view: investigate hypotheses with the potential to address the points cited above;

iv) from the student's point of view: being aware of his or her self-concept can help overcome certain learning obstacles and be aware of his or her perception of him/herself and how he or she sees him/herself in chemistry classes, helping him or her to create strategies to improve his or her performance.

Therefore, a tool like this, made for the context of Brazilian high school students, allows us to make comparisons and question teaching models. Effectiveness research that relates different teaching approaches (traditional, contextualized, experimental, etc.) and students' self-concept in chemistry can offer valuable information about the impact of approaches on students' views of themselves and their ability to learn chemistry.

Also, it is important to note that, with a negative self-concept, the student may stop interacting with the discipline's content, as he or she feels incapable and consequently unmotivated; and the lack of interaction can obstruct his or her development.

Finally, factors that transcend school walls can be considered and investigated, such as socioeconomic variables and their relationship with students' chemistry self-concept. The variables that can be investigated using an instrument like this are diverse. Thus, we highlight its potential to help researchers and teachers understand some of the factors related to Brazilian high school students' academic performance in chemistry.

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NOTES

1 The initial assessment for the ANOVA test is made by verifying whether the models are significantly different. This is done by a hypothesis test, whose H0 admits the equality of the models. To accept this hypothesis at a significance level of 95%, usually adopted, the p-index must be bigger than 0.05. When it is smaller, we reject the null hypothesis that says that the models are the same and interpret that they are statistically different. After this assessment, we use the AIC and BIC to determine the best-fit model.

2 On the interval scales, equal differences between numbers represent equal differences in the amount of the property or measured attribute (Golino & Gomes, 2015).

3 Logits are the units of measurement of the interval scale generated by the IRT models.

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