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Teaching Chemistry Based on the Stimulus Equivalence Model[1]

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Abstract: This study aimed to verify the effects of a procedure, based on the stimulus equivalence model, to teach naming 10 chemical elements, from their symbolic representations and their respective numbers and atomic models. Eight high school students participated. Four classes of stimuli were used: (A) name; (B) symbol; (C) atomic number; (E) atomic model of chemical elements. The following were performed: evaluation of the initial repertoire; teaching of conditional relations and testing of emergence of new conditional relations; evaluation of the final repertoire. From the teaching of three relations (AB, BC and BE), almost all participants presented at least 90% of correct answers (hits) in nine relations (BA, CB, AC, CA, EB, AE, EA, CE, EC); in the chemical elements naming (BD, CD and ED), seven participants obtained at least 80% of hits. The efficiency of teaching procedure for chemistry learning at the high school level has been verified.

Keywords: high school, chemistry, programmed instruction, behavior analysis, stimulus equivalence

Ensino de Química com Base no Modelo de Equivalência de Estímulos

Resumo: Este estudo teve por objetivo verificar os efeitos de um procedimento, elaborado com base no modelo de equivalência de estímulos, para ensinar a nomear 10 elementos químicos, a partir de suas representações simbólicas e de seus respectivos números e modelos atômicos. Participaram oito alunos do Ensino Médio. Utilizaram-se quatro classes de estímulos: (A) nome; (B) símbolo; (C) número atômico; (E) modelo atômico dos elementos químicos. Foram realizadas: avaliação do repertório inicial; ensino de relações condicionais e teste de relações emergentes; avaliação do repertório final. A partir do ensino de três relações (AB, BC e BE), a quase totalidade dos participantes apresentou, no mínimo, 90% de acertos em nove relações (BA, CB, AC, CA, EB, AE, EA, CE, EC); na nomeação do elemento químico (BD, CD e ED), sete participantes obtiveram, no mínimo, 80% de acertos. Verificou-se a eficiência da programação de ensino para o aprendizado de química em nível médio.

Palavras-chave: ensino médio, química, instrução programada, análise do comportamento, equivalência de estímulos

Enseñanza de Química basada en el Modelo de Equivalencia de Estímulos

Resumen: Este estudio tuvo por objetivo verificar los efectos de un procedimiento, elaborado con base en el modelo de equivalencia de estímulos, para enseñar a nombrar 10 elementos químicos, a partir de sus representaciones simbólicas y de sus respectivos números y modelos atómicos. Participaron ocho alumnos de la secundaria. Se utilizaron cuatro clases de estímulos: (A) nombre; (B) símbolo; (C) número atómico; (E) modelo atómico de los elementos químicos. Se realizaron: evaluación del repertorio inicial; enseñanza de relaciones condicional y prueba de relaciones emergentes; evaluación del repertorio final. En la enseñanza de tres relaciones (AB, BC y BE), la casi totalidad de los participantes presentó, como mínimo, el 90% de aciertos en nueve relaciones (BA, CB, AC, CA, EB, AE, EA, CE, EC); en el nombramiento del elemento químico (BD, CD y ED), siete participantes obtuvieron al menos el 80% de aciertos. Se verificó la eficiencia de la programación de enseñanza para el aprendizaje de química, a nivel de enseñanza secundaria.

Palabras clave: enseñanza secundaria, química, instrucción programada, análisis del comportamiento, equivalencia de estímulos

Chemistry, part of the Natural Sciences, is present in culture and social life; with research of materials and substances, develops scientific-technological knowledge with contributions that imply in economic, social and political reach.At school, although it is expected that the student will acquire knowledge that allows him or her to recognize the occurrence of chemical phenomena present in everyday life, and can act in a more adequate way before them, the System of School Performance Evaluation of the State of São Paulo – SARESP (Secretaria da Educação do Estado de São Paulo, 2014) shows that most of the students in the third year are in the Below Basic and Basic performance levels, showing that their education is

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precarious. The situation is critical, requiring the search for solutions or proposals that make the teaching of Chemistry in high school more efficient.

Behavior analysts have conducted research on the teaching of knowledge and skills; part of this research has been based on the stimulus equivalence model. The work referenced from equivalence studies was conducted by Murray Sidman in 1971. He verified the acquisition of reading by an individual with severe cognitive impairment. The studies of this researcher would lead to the later implementation of a research area referred to as stimulus equivalence.

Sidman (1971) used the matching-to-sample procedure (MTS). The participant, who had already received institutional treatment aimed at his or her needs, was able to name figures and identify them from the dictation of their names. Sidman taught the relation between spoken word (A) and printed word (C). When evaluating the effect of teaching, it was verified that there was an emergence of word reading (CD relation) and reading comprehension (BC and CB relations). In other words, the author taught one relation and new relations not taught have emerged. Sidman demonstrated the emergence of new behaviors.

Sidman and Tailby (1982) proposed the stimulus equivalence model, which describes a network produced from the teaching of some conditional relations. It is evidenced that there is equivalence between stimuli if relations emerge without direct training: reflexivity (A relates to A), symmetry (if A relates to B, then B relates to A) and transitivity (if AB and BC, then AC, that is, given the validity of the AB and BC relations, the AC and CA relations are also valid). In short, the equivalence between stimuli will be proven if these properties are present, meaning that the stimuli have become equivalent, exerting similar control over the individual's response. Studies based on the stimulus equivalence modelhave contributed to education. These studies have demonstrated that different repertoires can be taught with a high degree of precision.

In Brazil, the stimulus equivalence model has been widely used to investigate the teaching of academic abilities, such as reading (César & Moroz, 2015; Leite & Hübner, 2009; Machado & Haydu, 2012; Medeiros, 2011; Ponciano & Moroz, 2012; Reis, Souza & De Rose, 2009; Zanco & Moroz, 2015), Mathematics (Henklain & Carmo, 2013; Dalto & Haydu, 2015; Lorena, Castro-Caneguim,& Carmo, 2013), Music (Hanna, Batitucci, & Natalino-Rangel, 2016; Salvatori, Silva, Belem, Modenesi, & Debert, 2011), among others. Most of the studies presented intervention in the researcher-participant format, although part of them worked in a collective context, with intervention in the researcher-group format, like César and Moroz (2015), Machado and Haydu (2012) and Medeiros (2011).

As highlighted by Fields et al. (2009) "The procedural variables that lead to the formation of equivalence classes in the laboratory environment are already well documented" (p. 576). However, according to the authors, it is still necessary to demonstrate the possibility of using procedures based on equivalence for the teaching of more complex contents; in this direction, statistical teaching for university students was identified (Albright, Reeve, Reeve, & Kisamore, 2015; Fields et al., 2009) and neuroanatomy (Fienup, Mylan, Brodsky, & Pytte, 2016).

The field of Chemistry, however, is little studied, both in Brazil and abroad; it was located the study of Ferro (1993), which had as one of the objectives to teach the concepts of metals and nonmetals. According to the author, the stimulus equivalence model can be used in the teaching of Chemistry, which can be analyzed as a network of interrelated repertoires and acquired through equivalence relations.

Ferro (1993) used the equivalence model as a reference to teach those concepts. The author taught conditional discriminations, using name (metals x nonmetals), characteristics (solids at room temperature, good conductors x liquids at room temperature, bad conductors) and representative elements (Alkaline, Alkaline-earth, Earthy elements and Transition x Halogens, Amphigens, Carbon group and Pnictogen). After teaching, he verified the emergence of not explicitly taught relations, producing classes of equivalent stimuli. The work of Ferro is the closest to the present study.

Considering the importance of proposing productive alternatives for the teaching of Chemistry to students who are attending high school, the present study aimed to verify the effects of a procedure, elaborated based on the stimulus equivalence model, to teach the participants to naming 10 chemical elements, from their symbolic representations and their respective numbers and atomic models.

Method

The present experimental study was designed with phases of test (initial and final) and two of intervention, namely: Pre-Test – Teaching^{1st} Step – Teaching^{2nd} Step – Post-Test.

Participants

Eight students - aged between 15 and 17 years old, seven female students who attended regular classes in the second year of the high school of a state public school in the Metropolitan Region of Mogi das Cruzes (P3, P4, P10, P11, P12, P15, P16 and P18).

Instruments

MestreLibras Software (Elias & Goyos, 2010). Intended for teachers and other educators, it can assist in teaching academic skills. It allows to introduce sounds and images, making possible the use of the matching to sample (MTS) procedure and constructed response matching to sample (CRMTS) procedure,with randomization of the choices and record of student performance. There are consequences for the hits (having chosen to animate a coin by entering a piggy bank); for the wrong answers, the screen dims for a few seconds. The software generates a descriptive report of the participant's performance, identifying correct and incorrect choices, in absolute number and percentage; it also presents the number of trials and the time used to perform the activity.

Stimuli. The representative stimuli of ten chemical elements used in the teaching procedure and in the tests were visual. They are: (A) Printed Name: Carbon, Hydrogen, Oxygen, Nitrogen, Sulfur, Fluorine, Chlorine, Bromine, Iodine, Astatine; (B) symbol: C, H, O, N, S, F, Cl, Br, I, At; (C) atomic number: 6, 1, 8, 7, 16, 9, 17, 35, 53, 85; (E) atomic model: image of each atomic model corresponding to the chemical elements used. Examples of stimuli are shown in Figure 1.

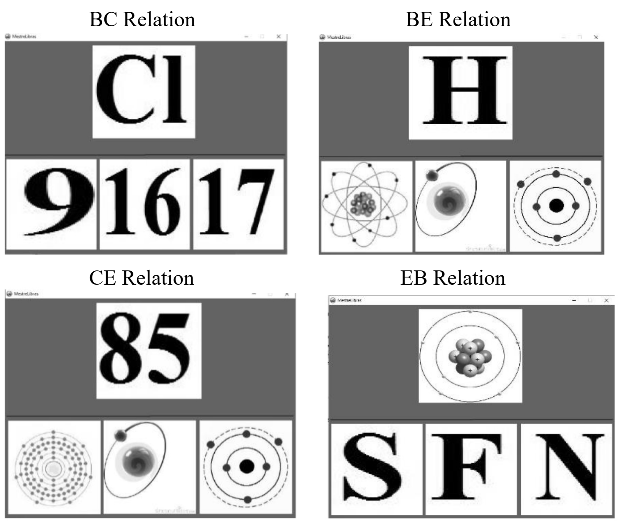

*Figure 1.*Examples of stimuli used in teaching (BC and BE) and relation test (EC and EB).

Microcomputers, printers, individual headsets were used in the computer room; the microcomputers were arranged in four rows, with five computers side by side.

Procedure

Data collection. Held in outside classes' hours (extra shift). The procedure consisted of: (1) Evaluation of the initial repertoire (Pre-Test). (2) Teaching of chemical elements, in two steps: 1stStep Intervention - Teaching of two relations (AB and BC) and test of the relations BA, CB, AC, CA and naming the chemical element from the symbol (BD relation) and from the atomic number (CD relation); 2ndStep Intervention - Teaching of the BE relation and emergency test of the EB, AE, EA, CE, EC relations and the naming of the chemical element from the atomic model (ED relation). (3) Evaluation of the final repertoire (Post-Test).

Evaluation of the initial repertoire (Pre-Test). The instructions were provided by the researcher; the activities were presented on the computer, and the participant's performance was recorded automatically. In the Pre-Test, as in the other tests performed, no consequences were released. The Pre-test was performed individually in a single session of a maximum of 50 minutes.

To evaluate the repertoire on the chemical elements, both selection responses (relations between name, symbol, atomic number and atomic model of the 10 chemical elements) as well as naming responses of the 10 chemical elements (from the symbol, the atomic number and the atomic model) were solicited. The chemical elements were: Carbon, Hydrogen, Oxygen, Nitrogen, Sulfur, Fluorine, Chlorine, Bromine, Iodine and Astatine.

For the evaluation of the initial repertoire of chemical elements,12 relations (AC, CA, AB, BA, BC, CB, BE, EB, AE, EA, CE, EC) between name (A), symbol (B), atomic number (C) and atomic model (E) of the 10 chemical elements were tested, each with five trials; was also evaluated the naming of the chemical element, from the symbol (BD), the atomic number (CD) and the atomic model (ED), with 10 trialsper relation. In all, there were 15 relations making a total of 90 evaluation trials.

Teaching and test of emergent relations. Each student was allocated in a computer, in which he or she do the activities.. During the intervention, the participants were in a collective context, although they performed activities at their own pace. The matching to sample (MTS) procedure was used. Three weekly sessions were held, with a maximum duration of 40 minutes, in the two steps.

In the 1stStep, 10 teaching blocks were conducted, each with three chemical elements: carbon-hydrogen-oxygen (Block 1); hydrogen-oxygen-nitrogen (Block 2); oxygen-nitrogen-sulfur (Block 3); nitrogen-sulfur-fluorine (Block 4);sulfur-fluorine-chlorine (Block 5); fluorine-chlorine-bromine (Block 6); chlorine-bromine-iodine (Block 7); bromine-iodine-astatine (Block 8); iodine-astatine-carbon (Block 9); astatine-carbon-hydrogen (Block 10). In each block, AB (chemical element name-chemical element symbol) and BC (chemical element symbol-atomic number of the chemical element) were taught. There were 12 trials per teaching relation, totaling 24 trials per block. The performance criterion was ≥ 90% of hits (one error), per relation taught; if not achieved, the participant was submitted again to the teaching. Once the criterion was reached in the block, the test of emergent relations was applied.

In each block, the emergent relations BA, CB, AC, CA, BD and CD were tested. There were 12 trials per relation, totaling 72 per block. In the BD and CD test, only the symbol or the atomic number was presented, and the participant was asked to give the name of the corresponding chemical element. The researcher recorded the participant's response. In the test of emergent relations, the criterion of performance was also 90% of hits, at least. The participant remade the trials of the teaching until reaching the criterion, condition to move to a new step.

In the 2ndStep, the relation BE (symbol-atomic model) was taught, integrating the atomic model to one of the elements of the relations previously taught, in this case, symbol (B). Four blocks were conducted: carbon-hydrogen-oxygen (Block 1); nitrogen-sulfur-fluorine (Block 2); chlorine-bromine-iodine

(Block 3); astatine-carbon-hydrogen (Block 4). There were 18 trialsper block, making 72 trials. The performance criteria and procedure were like those in 1thStep.

At each block, the emergence of EB, AE, EA, CE, EC and ED relations was tested, with 12 trials per relation, totaling 72 trials tested. Again, the performance criterion and procedure were like those in 1th Step. Figure 2 shows the teaching (filled lines) and tested (dotted lines) relations, indicating the integration of the atomic model (E) to the equivalence class previously formed (square).

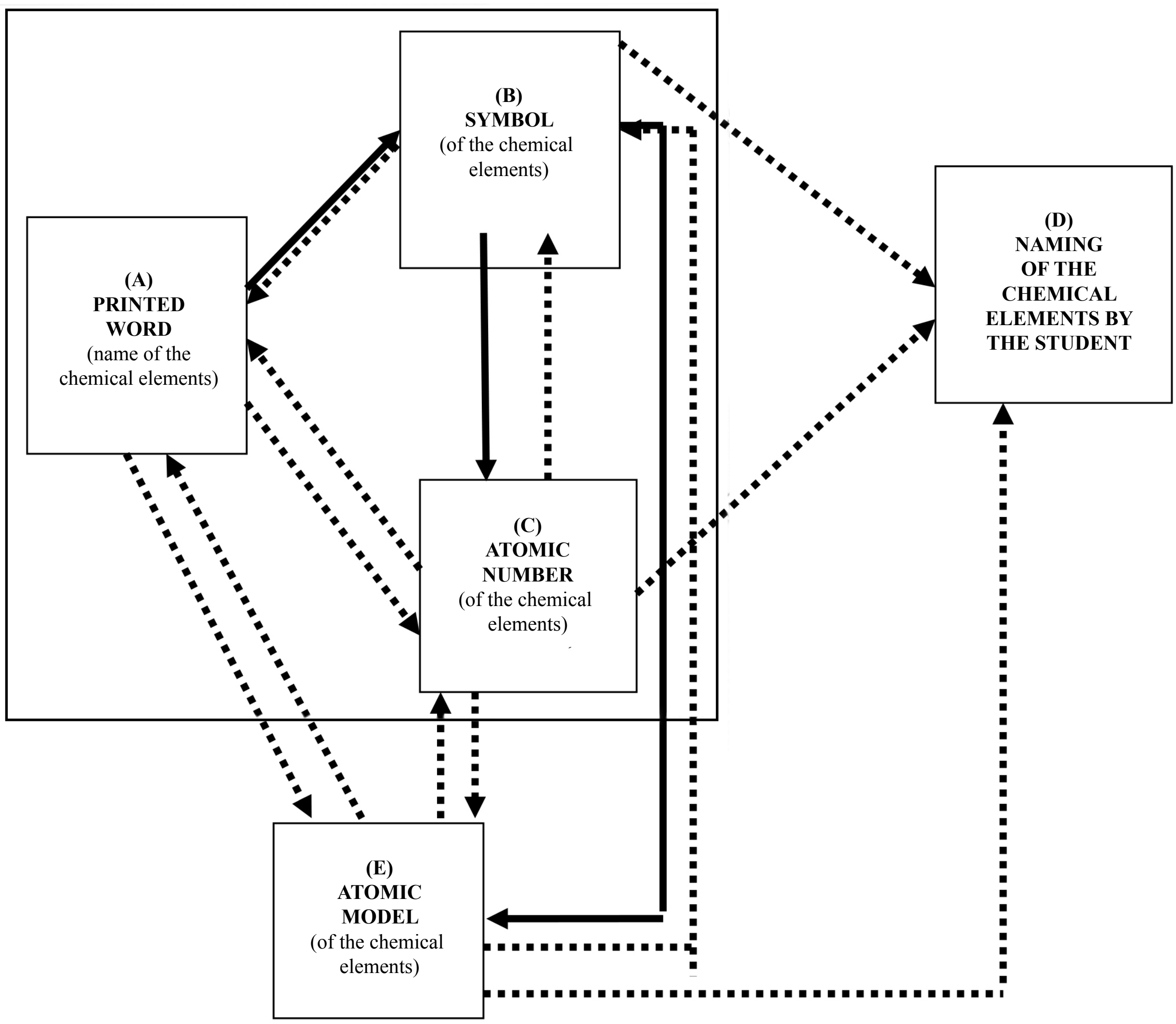

Figure 2. Diagram of relations taught (full lines) and tested (dotted lines). Based on De Rose diagram (2005).

Evaluation of the final repertoire (Post-Test). Once the two intervention steps were completed, the final repertoire (Post-Test) on chemical elements was evaluated. For this purpose, the same itens and procedures of the initial repertoire evaluation (Pre-Test) were reapplied. In Figure 3, the diagram of the experimental conditions of the study is presented.

Data analysis. The performance reports generated by the *MestreLibras* software were used. The average percentage of hits was obtained by relation taught and tested. The participants' performances were analyzed by focusing on the selection responses (relations AB, AC, BC, AE, BE, CE, BA, CA, CB, EA, EB, EC) and the naming of chemical elements (ED, BD and CD relations).

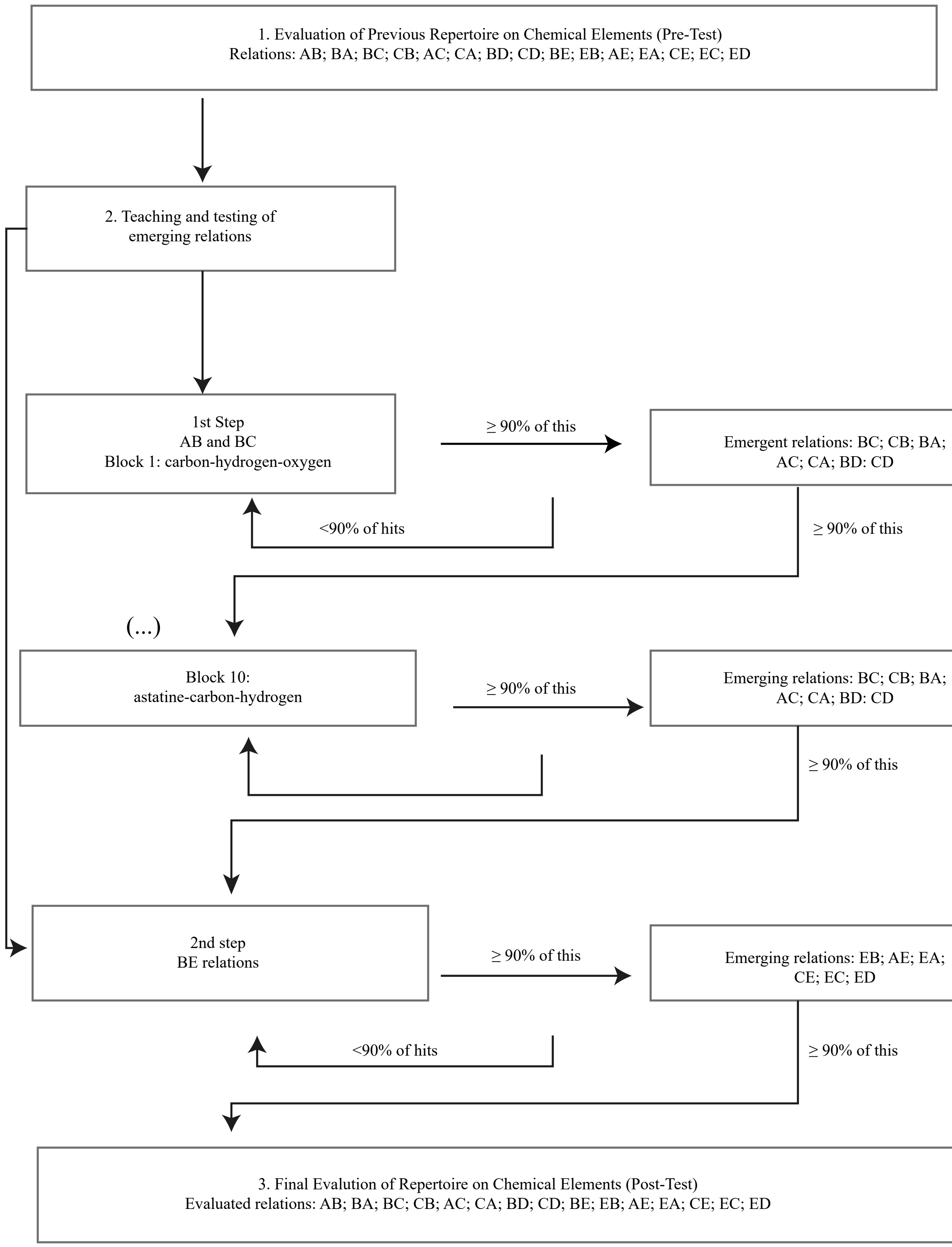

Figure 3. Diagram representative of the experimental design (Pre-Test, Teaching and test of emergent relations and Post-Test), with specification of the relations taught and tested

Ethical Considerations

The ethical requirements were fulfilled, in accordance with the Resolution of the National Health Council Resolution CNS / MS No. 196/96. Participants were informed that this was a research on teaching concepts of Chemistry, and participation was optional. The Free and Informed Consent Form was signed by the student's supervisor. The Research Ethics Committee of the Pontíficia Universidade Católica de São Paulo approved this research under the number of Opinion740.195 and CAAE 04684813.7.0000.5482.

Results

The performance of the participants in the different steps of the procedure will be presented below. Table 1 presents the percentage of participants' hits in the relations evaluated in the Pre-test and Post-test.

Table 1
Percentage of Hits, per Participant, in the Pre-Test and Post-Test

Participants	RELATIONS															
	AB		BA		BC		CE		AC		CA		BD		CD	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
P3	80	100	80	100	20	100	80	100	0	100	80	100	20	100	10	90
P4	80	100	80	100	20	100	60	100	60	100	80	100	20	100	0	60
P10	100	100	80	100	60	100	80	100	10	100	60	100	50	100	10	90
P11	100	100	80	100	60	100	80	100	20	100	60	100	60	100	10	90
P12	60	100	80	100	20	80	10	100	0	80	80	100	60	100	0	80
P15	80	100	80	100	10	100	20	100	10	100	60	100	20	100	10	80
P16	60	100	60	100	0	100	20	80	20	100	20	100	50	100	0	80
P18	80	100	60	100	0	100	20	100	0	100	10	100	44	100	0	100

Participants	BE		EB		AE		EA		CE		EC		ED	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
P3	100	100	60	100	60	100	60	100	80	100	100	100	10	80
P4	100	100	80	100	20	100	80	100	10	100	80	100	0	90
P10	80	100	20	100	20	100	80	100	10	100	80	100	0	100
P11	20	100	80	100	10	100	60	100	60	100	100	100	20	100
P12	20	100	80	100	10	100	60	100	20	80	20	100	0	50
P15	10	100	10	100	10	100	10	100	10	100	10	100	0	90
P16	20	100	10	80	80	100	10	100	20	80	20	100	0	90
P18	30	100	20	100	10	100	20	100	0	100	10	100	0	100

Performance of Participants in the Initial Evaluation (Pre-Test)

Considering the relations evaluated between the name of the chemical elements and the respective symbol, atomic number and atomic model (from AB to EC), the worst performances were those of P11, P12, P15, P16 and P18, because in a maximum five of 12 relations evaluatedthey presented between 80% and 100% of hits. The best performance was of P3, P4 and P10, since they reached between 80% and 100% of hits in seven and six, respectively, of the relations evaluated, a fact that indicates a certain level of knowledge of chemistry.

As for the naming of the chemical elements, from the symbol, atomic number and atomic model (BD, CD, ED relations) the results were clearly worse.Only when the symbols were presented (BD relation), there were 50% or 60% of hits, for P11, P12, P10 and P16. Already in the naming of the chemical elements from the atomic number (CD relation) and atomic model (ED relation), the participants practically did not present hits. These results reveal that only a few participants named part of the chemical elements as they visualized their symbols; however, they did not name them from their respective numbers and atomic models.

Performance of Participants in the First Step

During the teaching of AB and BC relations (1thStep), participants, except for P4 and P16, repeated the trials of BC relation to achieve the performance criterion (≥ 90% of hits). In the emergency test, all participants, except P15 (who had about 90% of hits in three of the six evaluated relations) and

P18 (who had 94% of hits in a single relation evaluated), all presented a maximum percentage of hits, or close to it. From the teaching of two relations, six relation not directly taught (stimulus-stimulus: CB, BA, AC, CA, stimulus-response: BD, CD) emerged, including naming the chemical element, both from the symbol and from the atomic number. The symmetrical and transitive relations emerged, indicating that the stimuli of sets A, B, and C became equivalent.

Performance of Participants in the Second Step

The BE relation was integrated into the equivalence class formed by three-member stimuli, and the emergence of EB, AE, EA, CE, EC and ED (naming of the chemical element from the atomic model) was tested.

The results obtained during the teaching of BE, as presented in Table 2, show that except for P10 and P18 that presented 100% of hits, the other participants repeated the teaching trials to obtain the criterion of performance. In the test of emergent relations (EB, AE, EA, CE, EC and ED), the performance was excellent, since all presented above 90% of hits in all relations tested, and six of the eight participants presented 95% of hits at least. It's worth noting the naming of the chemical element from the atomic model (ED relation), with maximum percentage of hits by all participants.

The results showed that from a single relation taught, six new relations emerged. With the integration of a new element (E) into the class of equivalent stimuli (A, B, C), new relations emerged between the integrated element and the other elements of the equivalence class previously formed.

Performance of Participants in the Final Evaluation (Post-Test)

At the end of the 2ndStep, the eight participants were again submitted to the evaluation of the repertoire of chemical elements (reapplication of the Pre-Test).

As shown in Table 1, in the Post-Test, in the relations between chemical name, symbol, atomic number (AB, BA, BC, CB, AC, CA, BE, EB, AE, EA, CE, EC), the participants matched all attempts, except for P12 in the BC, AC and CE relations and P16 in the CB, EB, CE relations, both with 80% of hits. The improvement in performance, in the relations to which the participant chose the alternative, was evident. As for the naming of the chemical elements (BD, CD and ED), except for P4, in the naming from the atomic number (CD) and P12, in the naming from the atomic model (ED), respectively with 60% and 50% of hits, the others presented between 80% and 100% of hits.

Comparing the data of the Pre-Test and Post-Test, there was an evident improvement in the percentages of hits of all the participants, highlighting the relations in which the atomic model was included, and for the naming of the chemical elements, from the symbol, the atomic number and the atomic model.

Discussion

The objective of the present study was to teach the participants to naming the chemical elements, from their symbolic representations and their numbers and atomic models. For this, a teaching program of conditional discriminations was proposed, based on the stimulus equivalence model, applied with the software *MestreLibras* in a collective context.

In the initial repertoire of the participants, students of the second year of high school, the results showed that, in the 12 relations between name (A), symbol (B), atomic number (C) and atomic model (E), the best performance occurred in the relation between name and symbol (AB and BA). In the relation in which the response of naming of the chemical element was evaluated, either from the symbol (BD), or from the atomic number (CD) or even from the atomic model (ED), it was verified that the best performance occurred in naming the chemical element from the symbol (BD), although in part of the chemical elements and by only some of the participants. The evaluation of the previous repertoire allowed to verify that participants who correctly selected the alternatives in the relation between the name and symbol of the chemical elements (AB and BA) could not oralize the chemical elements from their symbolic representation (BD). It became clear, therefore, that they were different repertoires. The results also indicated that the participants did not have the repertoire of Chemistry, target of the present study.

As for the teaching procedure (Steps1 and 2), the data indicated that it was adequate for the participants, since they did the teaching activities according to their own learning rhythm, reaching the expected performance level spending between 2 hours and 4 hours of activities, which does not even correspond to a normal period of classroom activities, since high school have, on average, 5 hours and 20 minutes a day. It was evident the economy of time in carrying out the activities (teaching and testing of emergent relations). This is an important result, since it shows that it is possible to teach and obtain excellence in performance in a short time, provided that the contingencies of teaching are planned, as highlighted by Skinner (1968/1972). It is also worth noting that such excellence in repertoire differs dramatically from what has been detected in the SARESP systematic evaluations carried out in the State of São Paulo (Secretaria da Educação do Estado de São Paulo, 2014).

Regarding the context of the intervention (Steps 1 and 2), it is important to highlight that the teaching was carried out in a collective situation, in the researcher-group format. Although the number of participants was reduced, compared to the number of students in a regular classroom in which the teacher interacts with an average of 40 to 45 students per class, the context of the present study approached the educational condition of the classroom. The feasibility of using procedures, based on the equivalence model, in a collective context, has been demonstrated,as happened in the studies by César and Moroz (2015), Fernandes and Moroz (2011), Machado and Haydu (2012) and Medeiros (2011).

In addition, it was possible to use procedures to teach more complex repertoires, as suggested by Fields et al.(2009).

Unlike the elementary school students who require the constant assistance of the teacher, the high school students already have a level of autonomy that favors their interaction with technological resources. In the case of programming in the *MestreLibras* software (Elias &Goyos, 2010), for example, they accessed the tasks and the performance report, evaluated their own performances on the tasks independently of the conference by the researcher, selected the tasks sequentially independently of the researcher, among other actions. Therefore, it is feasible to use equipment available in schools, such as computers and software, to teach the disciplines that make up the school program, opening other possibilities for teaching. To do this, the teacher must to know how to program the teaching, as indicated by Skinner (1968/1972), and to do so, he can take advantage of the students' computer skills, establishing new contingencies for the teaching-learning process in the educational context.

The emergence test of the CB, BA, AC, CA relations was applied after teaching AB (printed name-symbol) and BC (printed name-symbol) relations. The results showed the emergence of symmetrical and transitive relations, as occurred in the study of Ferro (1993), without having been directly taught. This result is in line with what was proposed by the stimulus equivalence model (Sidman&Tailby, 1982) and is confirmed in applied studies, as highlighted by Fields et al. (2009). The emergence of new repertoires occurred, but not only the receptive, that is, by selection response of the stimulus corresponding to the model. It was verified that the orally naming of the chemical elements emerged from the symbol (BD) and the atomic number (CD), in the first step of the intervention. The tests indicated that equivalence classes were formed by three-member stimuli: printed name, symbol and atomic number of the chemical element.

As described, in the second step of teaching the stimulus E (atomic model) was integrated to one of the components of the equivalence class, in this case the stimulus B (symbol). The BE relation (symbol-atomic model) was taught, and then the emergence test of the EB, AE, EA, CE, EC, ED relations was applied. The results showed again the emergence of all relations, without explicit teaching. With the teaching of a single relation containing the atomic model, there was the emergence of a selection repertoire (relations EB, AE, EA, CE, EC), and productive repertoire, such as the naming the chemical element from the atomic model (ED), without having been directly taught. The emergence of this last relation is important, since it indicates that the integration of a new stimulus (E: atomic model) to the class of equivalent stimuli allowing the amplification of the emergent relations.

According to the stimulus equivalence model, it is not necessary to teach explicitly all relations when a new element is integrated to aequivalence class. It is enough integrate the new member to one member of the equivalence class; thus, the teaching of only one relation is enough for the others to emerge. As highlighted by De Rose (2005):

> These relations are in principle independent but can integrate as some of them are learned. When this integration occurs, new relations not explicitly taught can emerge: the teaching of some of them results in transference to new relations, with little or no explicit teaching of these new relations (p. 42).

As pointed out by Arntzen (2010), the works of Sidman (1971) generated great impact, not only on basic research, but also on applied research, passing the researchers to focus different skills with different types of participants. Studies based on the stimulus equivalence model permit understand how behaviors appear that were not directly trained, fact evidenced in the present work.

In short, post-teaching evaluation indicated clear difference in the students' repertoire, comparing to what was presented before teaching, allowing to conclude that the participants learned to relate the atomic model, symbols and atomic numbers to the name of the chemical elements. The evident difference presented in the Post-Test indicates that the proposed teaching program was effective in promoting the improvement of participants' repertoire. It demonstrates the feasibility of using procedures based on the stimulus equivalence model to teach, in an efficient way, complex repertoires, such as those on the field of Chemistry.

Finally, reference should be made to the fact that, in the present study, no control group was used, making it impossible to compare the results obtained by using technology derived from the equivalence of stimuli and those obtained by other teaching procedures. Although this absence does not invalidate the conclusion that the teaching procedure adopted had positive effects, such a comparison could provide data that would allow us to present new arguments indicating the effectiveness of this technology in the education area, especially in the teaching of Chemistry.

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