CONCEPT MAPS WITH ERRORS AS AN ASSESSMENT TASK IN ELEMENTARY SCHOOL

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Abstract. The use of concept map as an evaluation tool in elementary education is a differentiating factor that helps the teacher's work to understand how the student learns and modifies his knowledge structure from previous knowledge. Our research group is a pioneer in the development of tasks based on the use of concept maps with errors (CMap/E). In this model of assessment, teacher is the one who elaborates the CMap and, in doing it, intentionally inserts propositions with conceptual errors. In this situation, the student's knowledge structure is not self-declared, but can be inferred from the identification (or not) of these errors, which come from their performance in the task. The purpose of this work was to verify the effectiveness of CMaps/E task as an evaluation tool in science teaching in the final years of elementary school according to the Brazilian curricular basis. For this, 45 CMaps/E and 45 true or false tests were collected. The subject covered in this evaluation was Chemical Functions. The true or false test was used to verify the existence of correlation between the students' responses in this task and in the CMap/E. After this verification, the students' performance in the CMap/E task was used to classify the propositions in easy, moderate and difficult, through descriptive statistical analysis. The results showed that CMap/E is useful as an assessment tool in elementary school, and allow the teacher to extract relevant information about the students' conceptual understanding quickly and accurately.

Keywords: concept maps with errors, assessment, Science teaching, elementary school

1 Introduction

Teachers face several challenges in their pedagogical practice, from curricular organization, teaching work planning, complementary activities and structuring of the evaluation process and interlacing the objectives with the instruments used to obtain information about the students' performance in relation to their own learning process.

The use of evaluation tools that do not rely only on superficial memorization is one of the current educational challenges (Toigo, Moreira & Costa, 2012). A tool used for teaching and evaluation purposes is the concept map (CMap) that allows structuring information for the knowledge's construction (Kinchin, 2016; Moon et al., 2011; Novak, 2010). The CMap can be a teaching resource incorporated into the classroom daily routine, in order to provide various information from those afforded by other instruments. Ruiz-Primo & Shavelson (1996) point out that the evaluation tasks involving CMaps should provide:

i. a task that invites the student to provide information about their knowledge structure in a specific domain;
ii. an appropriate response format for the task, and
iii. an appropriate scoring system for the teacher to assess student performance.

For the elaboration of a concept map that benefits the characteristics pointed out by Ruiz-Primo and Shavelson (1996), there is a need for training in the technique (Aguiar, 2012) of CMaps so as to be synthetic and well explanatory. However, some factors interfere in this training; among them, the demand of enough time for the execution of the activity (must be compatible to the minimum time necessary to train the students in the task of preparing the CMaps). In addition, time spent by the teacher for the correction and evaluation of each CMap made by his students, in some cases hundreds of CMaps, according to the class size (McClure et al., 1999). However, such problems are minimized when the teacher prepares the CMap for use in the evaluation.

1.1 Elementary school: The concept maps with errors in the discipline of Sciences

The teaching of science is a multifaceted and relevant discipline to relate and interlink the experiences that occur with the environment, with the human being and the technological transformations present in our society. Bizzo (2009) states that teaching science is a way of comprehension and understanding the world. The author also states that it is only by teaching science that students can understand the importance of scientific knowledge, since the discipline of science offers a more scientific view of the real world. Moreover, it is in the school context, in elementary school, that scientific knowledge begins to be developed. The school scientific knowledge in primary education makes possible to construct relations, orientation to citizenship, the formation of active citizens, consumers and responsible users of new technologies (Viecheneski & Carletto, 2012). Thus, "the teaching of science in the school is of vital importance and has its results improved if it enlarges its action already in the first years of the elementary school" (Malacarne & Strieder, 2009).

The concept map is a viable tool to visualize the students' alternative conceptions and favors a teacher's mediation of the learning process with the purpose of adjusting the student's knowledge structure with new conceptual relations about scientific knowledge in the Sciences classes. The use of the concept map in the classroom in elementary school - final years - is not a common task. According to Toigo, Moreira e Costa (2012), concept maps in general are used in higher and secondary education (high school) rather than in elementary education. In such manner, using the concept map as an evaluation tool in elementary education is a differentiating factor that helps the teacher to understand how the student learns and modifies his knowledge structure from previous knowledge.

Concept maps are graphical tools for organizing and representing knowledge by indicating the relations between concepts. They can be used in many different ways to assess the individual's understanding. The concepts are representative aspects that describe and particularize a regularity or an object, being presented by words and/or expressions inside geometric figures. The relationships between them are indicated by lines with arrows, to which are attached explanatory phrases - link phrases - that interlink and give meaning to the keywords (Cañas et al., 2000; Novak, 2010; Davies, 2011).

Our research group is a pioneer in the development of tasks based on the use of concept maps with errors (CMap/E). In this model of evaluation, the teacher is the one who elaborates the CMap and, in so doing, intentionally inserts propositions with conceptual errors. When teachers create their CMaps with errors to be identified by students, the spending time is decreased in many ways (Figure 1). In this situation, the student's knowledge structure is not self-declared, but can be inferred from the identification (or not) of these errors, that comes from their performance in the task (Correia et al, 2016). In the conceptual map with error, the teacher structures the map correctly according to the content addressed and then changes some words in the link phrases so that the proposition become incorrect (it is possible to see examples in Figure 2 in the next section). Then, the task for the student is to find these errors and correct the proposition to form an appropriate semantic unit. The purpose of this work is to verify the effectiveness of the concept mapping with errors task as an evaluation tool in the science teaching in the final years of elementary school according to the Brazilian curricular basis.

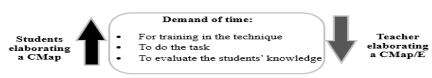

Figure 1: Demand of time need when students elaborate a CMap and when the teacher elaborates a CMap/E. When students do the map the use of time is higher than when the teacher prepares a CMap/E.

2 Methods

2.1 Materials

The collection of CMaps (n=45) and the true/false test (n=45) occur during the Sciences class offered within the curriculum of basic education at a school located in Paraná State, Brazil, for student of 9th grade of elementary school. The students' age average is 14 years old. The topic addressed in the evaluation was Chemical Functions involving four basic contents: (i) acids; (ii) bases; (iii) salts and (iv) oxides.

The teacher elaborated the CMaps containing 28 propositions and later modifications in 14 linking phrases were made to include conceptual errors at propositions 1, 3, 7, 8, 11, 12, 13, 14, 17, 19, 20, 22, 24, 28 (Figure 2). Another evaluative instrument used was the true or false test (t/f), which was also elaborated by the teacher and contained the same content as those on the propositions of the concept map. Students should read and mark if the statements as true or false according to their understanding (Table 1). To avoid random responses, students had the option of "I prefer not to answer" in all statements. In both tasks, students should explain why the proposition and the statement were incorrect.

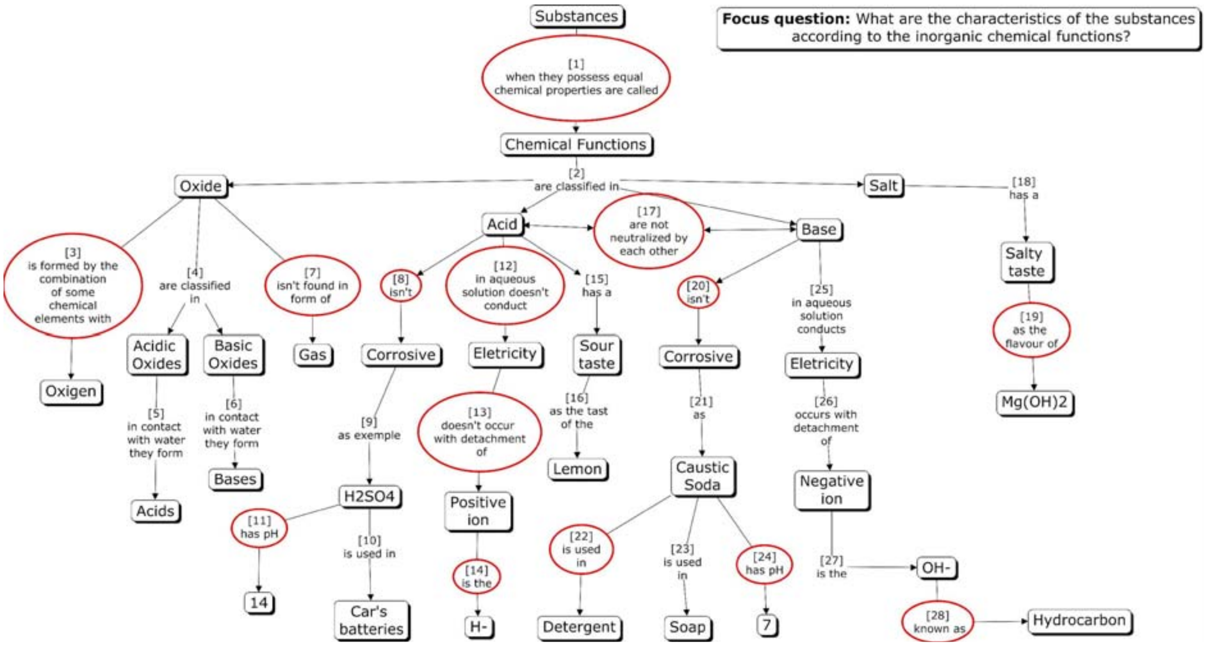

Figure 2. Full concept map with error used for the assessment. The incorrect propositions are in red circles. This map has been translated from Portuguese.

2.2 Data Collection and Procedures

The materials were collected in two different days (Figure 3):

- On the first day, the t/f was collected. Students received a sheet with a standard header from the educational institution and instructions for doing the activity. The teacher read aloud the instructions as she distributed the activity. Then clarified that the students should indicate if the sentence was correct or not and if they had doubts they could indicate in a maximum of 3 times the “I prefer not to answer” option. The time for reading the instruction of the task and clarify doubts lasted 10 minutes and the time for the realization of the task was 40 minutes (total time of a lesson);
- On the second day, the CMap containing the incorrect propositions was collected. The instruction procedure was the same as the previous day and the time to perform as well.

2.3 Data Analyses

2.3.1 Validation of CMap/E as an evaluation tool

Our research group believes in the potential of the CMap/E as evaluation activity, to support our belief we did a validation to show the potential of this tool, once the t/f task is a traditional and widely used evaluation tool.

The students' response to the exercise using CMap/E was coded as follows: 1 point for each identified error and no point for unidentified errors when it came to incorrect propositions. The correct propositions were also considered, since they had subjects corresponding to the t/f statements. In these cases, the student received 1 point for considering it correct and no point for considering it wrong. The students' response to the t/f was simply codified: they received 1 point when judging properly the statement, and 0 when making a mistake.

1	SUBSTANCES has proprieties called CHEMICAL FUNCTIONS	15	SALT is also a CHEMICAL FUNCTION
2	CHEMICAL FUNCTIONS are classified as ACID, BASE, SALT AND OXIDE.	16	BASE is CORROSIVE.
3	ACID has a SOUR TASTE.	17	CORROSIVE as CÁUSTIC SODA
4	SOUR TASTE as the flavour of LEMON.	18	CÁUSTIC SODA is used in DETERGENTS e SOAP.
5	ÁCID is CORROSIVE.	19	CÁUSTIC SODA has pH 7.
6	CORROSIVE as, H2SO4.	20	BASE in aqueous solution conducts ELETRICITY.
7	H2SO4 is used in CAR'S BATTERIES	21	ELETRICITY with detachment of NEGATIVE IONS.
8	H2SO4 é has pH 6.	22	NEGATIVE IONS as OH-
9	ÁCID in aqueous solution conducts ELETRICITY.	23	OH- is known as HIDROXYL.
10	ELETRICITY with detachment of POSITIVE IONS.	24	BASE has an ASTRINGENT TASTE.
11	POSITIVE IONS as H+	25	ASTRINGENT TASTE is a characteristic of GREEN BANANA flavour.
12	ACID neutralizes BASE as result they form SALT.	26	ÓXIDE is found in the form of GAS.
13	SALT has a SALTY TASTE.	27	ÓXIDE is formed by the combination of a chemical element with OXIGÊN.
14	SALTY as the flavour of Mg(OH)2	28	OXIDE reacts with water to form ACIDIC OXIDES and BASIC OXIDES.

Table 1: True or false tests used for the assessment. These statements were translated from Portuguese.

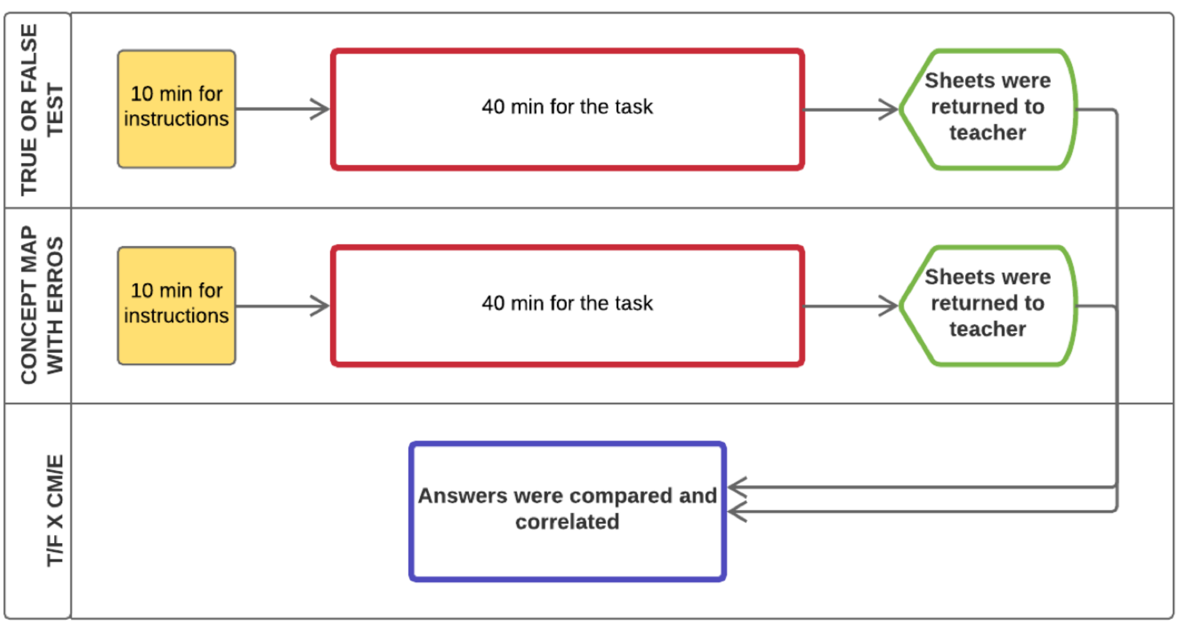

Figure 3. Chart that shows how was the collection materials procedures.

The combination of responses in the activity with CMap/E and in t/f resulted in a numerical pair (x, y), where *x* refers to a CMap proposition and *y* refers to t/f. This allowed us to verify the validation of the activity, where (0,0) and (1,1) confirm the validation and (0,1) and (1,0) do not confirm the validation as follows:

- (0,0): Student did not identify the error on the concept map and mistaken in the t/f statement;
- (1,1): Student identified the error on the concept map and answered correctly the statement;
- (0,1): Student did not identify the error on the concept map answered correctly the statement.
- (1,0): Student identified the error on the concept map and mistaken in the t/f statement;

The frequency was calculated for each of these numerical pairs.

2.3.2 Getting information from the CMap with errors assessment task

The performance of students was used to classify the propositions into easy, moderate and difficult.

A matrix S (45x28) containing the students' answers for all propositions in the CMap/E was used to run the hierarchical cluster analysis (HCA) using the Pirouette v. 4.5 (Infometrix, Bothell, WA, USA). All answers in this matrix were coded using 0 and 1 to represent not found and found errors by the students, respectively. The aim was to look for natural groups of students with similar response patterns.

3 Results and Discussion

3.1 Validation of CMap/E as an Evaluation Task

Table 2 describes the results obtained (mean and standard deviation) for each of the four numerical pairs considered in this study, those that confirm the validation (0,0 and 1,1) and those that do not confirm the validation (1,0 and 0,1). There is also a comparison between the frequencies found for the propositions that were correct and those that were wrong.

Comparison of propositions Mean (SD)	**Categories that confirm validation**		**Categories that do not support validation**	
	0,0	1,1	1,0	0,1
With error (n=14)	31% (25%)	34% (29%)	14% (17%)	20% (19%)
Without error (n=14)	4% (5%)	61% (24%)	26% (22%)	4% (5%)
All (n=28)	18% (23%)	47% (29%)	20% (20%)	12% (16%)

Table 2: Global analysis of the exercise considering the correct propositions and propositions with error.

Considering all the propositions of CMap/E (n=28), a total of 65% of validation was obtained. Among these, 47% validate for the good performance of students in CMap/E and t/f task (1,1) and 18% validate for error in both tasks (0,0).

The analysis also revealed that 32% of the propositions were not valid. Among them, 20% refers to the students who identified the error in the concept map and mistaken in the t/f statement (1,0) and 12% are referring to those who did not identify the error on the conceptual map answered correctly the statement (0,1). These results are important because they reveal information to the teacher about the quality of their assessment materials. For example, the 1,0 category (good performance in CMap and poor performance in t/f task) informs the teacher that in the t/f task are statements that could be clearer written, since students correctly judge propositions carrying the same content in CMap/E. That is, students understand content as long as it is within a context.

Therefore, the CMap/E is a valid assessment task because: (i) Results obtained with this task are similar to the results obtained from t/f task in 65% of cases. (ii) The CMap/E decreases the ambiguities that can occur when a statement is isolated, since CMap/E puts all content within the same context by responding to a focal question.

3.2 Students' Understanding Evaluation

The frequency results for the numerical pairs confirmed the validation of the activity with CMap/E in 65% of the propositions. With this result was made a hierarchical cluster analysis (HCA) using the Pirouette v. 4.5. The students' scores in the 28 propositions of the CMap/E were considered, obtaining a data matrix 45X28.

The HCA confirmed the existence of 3 groups of propositions with similarity 0.659. These groups were characterized as easy propositions, moderate and difficult, according to the students' performance in each one. The relation of the propositions belonging to the 3 groups found in the HCA was as follows:

- Easy propositions:
    - P2: *Chemical Functions − are classified in → Oxide, Acid, Base and Salt*
    - P4: *Oxide − is classified in → Acidic Oxides & Basic Oxides*
    - P7: *Oxide − isn't found in form of → Gas*
    - P8: *Acid − isn't → Corrosive*
    - P9: *Corrosive − as example → H2SO4*
    - P10: *H2SO4 − is used in → Car's batteries*
    - P15: *Acid − has a → sour taste*
    - P16: *Sour taste − as the taste of the → Lemon*
    - P17: *Acid − are not neutralized by each other → Base*
    - P18: *Salt − has a → Salty taste*
    - P21: *Corrosive − as → Caustic Soda*
    - P23: *Caustic Soda − is used in → Soap*
    - P25: *Base − in aqueous solution conducts → Electricity*
    - P26: *Electricity − occurs with detachment of → Negative ion*
    - P27: *Negative ion − is the → OH-*

- Moderate propositions:
    - P5: *Acidic Oxides − in contact with water they form → Acids*
    - P6: *Basic Oxides − in contact with water they form → Bases*
    - P12: *Acid − in aqueous solution doesn't conduct → Electricity*
    - P13: *Electricity − doesn't occur with detachment of → Positive ion*
    - P14: *Positive ion − is the → H-*
    - P20: *Base − isn't → corrosive*

- Difficult propositions:
    - P1: *Substances − when they possess equal chemical properties are called → Chemical Functions*
    - P3: *Oxide − is formed by the combination of some chemical elements with → Oxygen.*
    - P11: *H2SO4 − has pH → 14*
    - P19: *Salty taste − as the flavour of → Mg(OH)2*
    - P22: *Caustic Soda − is used in → Detergent*
    - P24: *Caustic Soda − has pH → 7*
    - P28: *OH- − known as → Hydrocarbon*

Figure 4 shows the percentage of students who judged correctly each proposition. The black bars indicate the propositions with errors while the gray bars indicate correct propositions.

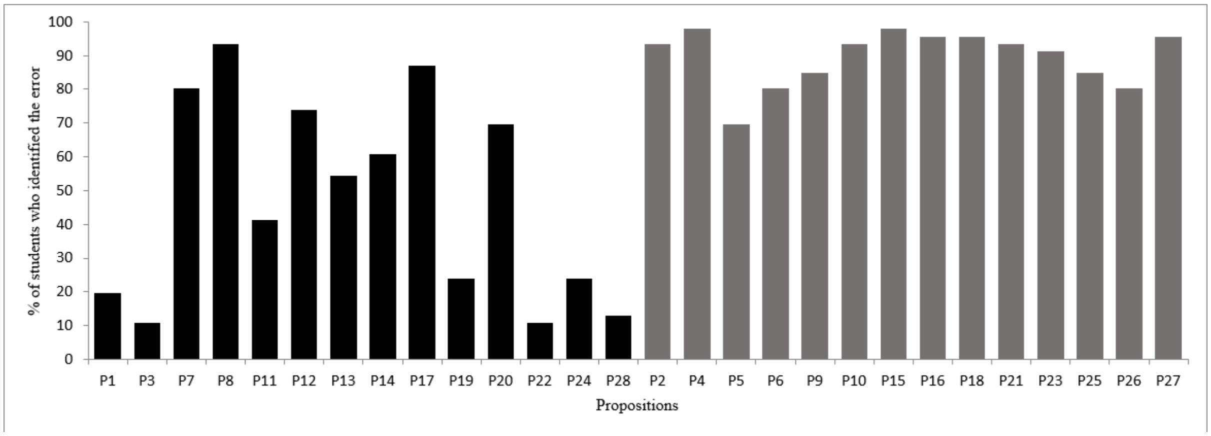

Figure 4. Graph obtained from performance of students in the judgment of propositions. The black bars indicate the propositions with errors while the gray bars indicate correct propositions.

The propositions where the students had the highest performance were the 4 and 15, both with 97.8% accuracy. Proposition 4 (*Oxide − is classified in → Acidic Oxides & Basic Oxides*) involved the progressive differentiation of the CMap that carried information about the oxides. While proposition 15 (*Acid − has a → sour taste*) involved the branching of the CMap that treated the acids. The propositions 8, 9, 10, and 16 were also in the group of easy propositions, these propositions carried content about the acids as well. Therefore, the CMap/E task showed the teacher that, in general, students are able to understand the content of the acids well.

In elementary school, according to the Brazilian curricular basis, it is usually the students' first contact with concepts about inorganic chemical functions. However, in general, students already have previous knowledge about acids, because they often hear that "lemon is an acid fruit," then relate acid to sour and corrosive things. It is known that previous knowledge is a key point for meaningful learning (Ausubel, 2000), and for this reason, students can achieve a good performance in propositions that bring concepts about acids.

The opposite occurs with propositions about the bases. It is not common for students to hear that bases are also corrosive; usually they assume that the base is the opposite of acid. For this reason, proposition 20 (Base - isn’t → corrosive) is among the moderate propositions, with 69.5% accuracy. Moreover, among the moderate propositions, there were those that carried introductory concepts of electrochemistry, for example proposition 12 (Acid - in aqueous solution doesn't conduct → Electricity). According to the Brazilian curricular basis, students will learn electrochemistry in more depth in high school. Therefore, it was expected that the students would have difficulty in judging the propositions related to this topic.

The difficult propositions are those that carry nomenclatures of chemical functions. For example, proposition 28 (*OH- − known as → Hydrocarbon*) got 13.0% accuracy, and proposition 19 (*Salty taste − as the flavour of →* $Mg(OH)_2$) got 23,9% accuracy. The equivalent result was observed in propositions about pH as proposition 24 (*Caustic Soda − has pH → 7*), with a success of 23.9%. These results show the exact content that needs to be reinforced with the class, revealing valuable information to the teacher about the difficulties of their students, allowing him to intervene and provide feedback to his students more quickly and accurately.

Precise and timely feedback is critical to foster pedagogic resonance, i.e., the bridge between teacher knowledge and student learning. The need for rapid intervention is clear to avoid the accumulation of conceptual problems that undermine deep learning (Kinchin, Lygo-Baker & Hay, 2008; Trigwell & Shale, 2004; Novak, 2002). We believe that CMap/E is an innovative and effective assessment tool in enabling the teacher to obtain such detailed information about the conceptual understanding of their students during the teaching process.

4 Conclusion

Misconceptions made by students during the teaching-learning process in science become an important moment for the detection of learning obstacles. The actions of finding them, understanding them, determining their causes and negotiating meanings are indispensable tasks for the teacher, and can be facilitated by the use of CMap/E. Especially when the number of students is excessively large, which would make it impossible to use concept maps made by students as a form of evaluation. The practicality of CMap/E allows them to be used on a large scale, and in virtual learning environments. The possibility of the teacher giving feedback to the student more quickly promote a greater understanding of the contents, greater appropriation of new knowledge and consolidation of prior knowledge.

The CMap/E presented itself as a relevant instrument to be used in the evaluation process, as it evidenced its informational character. The most important information came from the students' ability to find the errors in the propositions, showing how much the learner knows and what he has yet to learn this is an evidence of a formative evaluation (Luckesi, 2003).

The possibility of using CMap with errors for any interdisciplinary subject and embedded into online learning environments suggests this is only the beginning of a promising task full of innovations involving concept mapping and learning assessment. Future studies will be conducted to analyze the possibility of using CMap/E in higher education and in online courses.

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