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WHAT DO YOU KNOW ABOUT GENETICS? CONCEPTUAL MAPPING AND ITS CORRELATION WITH TRADITIONAL ASSESSMENT AND ACADEMIC PERFORMANCE

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Abstract: Currently teachers need to master contents, build them in open situations and use the student's interest, making profit of strategies and methodologies that promote meaningful learning; assessment should have diagnostic and formative means, undergoing a co-analysis of student´s work and the regulation of their efforts, rather than by scores and ratings. Taking into account the influence that way of teaching/assessment has on learning, we investigated the profile of the conceptual mapping of Bachelor's Degree in Biological Sciences' students on the focal question: "What do you know about Genetics" and its correlation to academic performance verified through tests and trials. For this, we have chosen students enrolled in the course Instrumentation for Teaching Genetics, creating categories for the areas/courses to which the concepts presented were related. Forty-six percent of the students presented concepts related to only one category, 32.2 % cited two categories, 13.8 % made reference to three categories , while only 2.3% (2 students) mapped concepts of four of them. Even when more than one concept/area were mentioned they were at uncorrelated categories suggesting a restricted significant learning. The correlation between the scores of academic achievement and maps showed a strong correlation for only 15 % of the sample, the weak correlation shown by the majority of students may indicate that traditional assessments, based on repetition and memorization techniques, do not constitute adequate evaluation tools for "learning" check out. Thus, we suggest that inserting the conceptual maps in the formal assessment system, for diagnosis and formative means, would be a more appropriate strategy.
Keywords: Conceptual mapping, learning strategies and methodologies, diagnostic and formative assessment, learning genetics.

1 Introduction

1.1 Genetics teaching in Brazil

In Brazil, although the scientific and technological innovations are part of high school *curriculum*, most students are not instructed to contextualize their school acquainted biology knowledge, especially those subjects related to genetics, to their real lives (Moura, *et al*., 2013). The student does not make the correlation, for instance, between subjects such as cell cycle; composition and functioning of the DNA molecule, as the basis needed for the development of transgenes technology (Moura *et al*., 2013). Thus, both high school and college students, most of the times, consider Genetics contents difficult and not interesting (Klautau *et al*., 2009; Oca, 2005).

The understanding of biology in high school allows the student to assimilate, to reflect, to be critical and it can deepen their knowledge in relation to biological processes, furthermore it allows the understanding of their importance in technological construction and products generation (Krasilchik, 2000).

Advances in Science and Technology, present in daily life, lead teachers to think in different pedagogical methodologies and new proposals that favors "scientific literacy" and contextualized learning. There is an increased need for education professionals to encourage meaningful learning of concepts based on scientific explanation connected to the day by day life in an attempt to awaken student interest and provide subsidies for the construction of their knowledge (Vieira, 2010).

According to Perrenoud (2000), teachers need content mastering to work them in usual situations as well as in complexes tasks, using students' interests, exploring daily events; in other words favoring active assimilation and exchange of knowledge. This skill allows teachers finding different motivating ways to teach refractory subjects. Without this general perception and contextualized, the teacher ends up acting in a superficial manner and inducing content memorization.

However, as discussed by authors such as Justina and Ferrari (2010), Andrade (2011), Schneider and colleagues (2011) when asked about basic concepts in biology, focusing on genetics, undergraduate students presented basic and shallow concepts without bond with technological advances and their contextualization. Accordingly, regarding teachers and biology teaching, Trivelato (1995) states that only with deep knowledge of the contents, and feeling secure about them, it that teachers will have a perception of what is essential to be taught.

In order to allow teachers to act towards meaningful learning, Carvalho and Gil-Pérez (2009) discuss how important it is that contents during undergraduate courses, especially for future teachers, are also addressed in a meaningful way allowing that newborn teacher, through their own learning process, the construction of a model to be reproduced in their professional practice. It is not enough to simply insert new terms/classifications and leave them as "black boxes" for the students. Students need to rebuild these terms in a prior conceptual networks. This (re)construction allows the student to overcome the limitations of the fragmented and/or reductionist view usually associated with knowledge of Biology/Genetics, making itself critical about knowledge (Justina, Meglhioratti and Caldeira, 2012). Thus, assessment is deeply connected to this process and it cannot be dissociated.

1.2 Fundamentals of Assessment

Several innovations have been proposed in education, however, assessment remains as a finalist and classificatory character going against the proposed at the Guidelines for the National Curriculum that defines assessment:

> "... Is an active part of the training process, as it allows to diagnose and overcome gaps, assess achieved results considering the competencies to be made and identify any necessary changes route" (Brazil, 2002, p.32).

Piletti (2003) argues that the assessment should address the learning process as a whole, focusing at the advance of the students as well as at the teachers´, occurring in mutual way. Moreover, “[...] it is not only reduced to scores. Its connotation expands and moves, in order to verify the extent to which students are achieving the proposed goals for teaching-learning process” (Hadji, 2001, p. 286).

For effective implementation, the assessment should be based on diagnostic, formative and summative profiles (Haydt, 2002; Libâneo, 1994; Piletti, 1987). The diagnostic profile of the assessment requires planning and direction of the teaching learning process by means of verifying knowledge and skills in a group of students on the addressed issue.

Formative assessment, continuously conducted, aims to track student´s performance mainly offering possibilities to point out failures and successes of both students and teachers, adapting methods of teaching to the learning group´s needs. The results of this formative profile allow performing corrections and methodological adjustments if necessary. This function is also relevant with regard to stimulation and motivation necessary during the learning process, functioning as a control (Haydt, 2002).

At last, the summative task classifies students´ quantitative or qualitative levels of achievement, often at the end of a learning step, aiming a promotion to a next level of the educational hierarchy. Considering the three evaluative functions, the assessment according to Perrenoud (2000) should have primarily a formative character, undergoing a co-analysis of the student´s work and the meaning of their efforts, rather than by scores and ratings.

1.3 Using the conceptual mapping

The conceptual map is a representation of a set of conceptual meanings anchored in a structural network of propositions belonging to that person. The idea of conceptual map was created by Novak in 1972, based on the learning psychology of Ausubel (Novak and Cañas, 2008). From the moment that one is aware of the previously anchored concepts it is possible to make the relationship between these and the new concepts acquired (Novak, Gowin, 1996).

Novak and Cañas (2008), citing Ausubel, discuss the importance of the way that new concepts are presented because it will indicate whether or not the student will be able to anchor these concepts in their structural network. When the concepts described and communicated to the student are not anchored to its network of meanings this will lead to mechanical learning. Meaningful learning occurs when concepts are identified autonomously by the student and anchored in its structural system, taking long-term significance. Thus, strategies and teaching methodologies and assessment, enabling the relationship of new concepts with pre-existing structural network in the student concepts are essential to foster meaningful learning.

According to Novak and Gowin (1996), the conceptual map, in addition to being a teaching strategy, explores relevant concepts that students already possess, and can be used as a research tool for the structural network preconceptions of students, as well as a tool to assess learning. According to Romero (2007), the conceptual mapping is a strategy to ease the task of "learning how to learn", it allows the understanding of the structure of a subject, enabling the understanding of the construction and significant relationship between concepts of certain content.

In this context, this paper aims to investigate the profile of the conceptual mapping of students of the Bachelor's Degree in Biological Sciences, offered through the consortium CEDERJ on the focal question: *'What do you know about **Genetics**?'*, demonstrating their concepts and related meanings and subsequently identify the correlation between the results of their maps and academic performance. Traditionally, in a summative assessment process, academic performance is verified through tests and trials.

2 Methodology

2.1 Context of the research - case study

The Bachelor's Degree in Biological Sciences, target of this research, is offered by the Consortium CEDERJ (Centre for Distance Education of the State of Rio de Janeiro) through three of the consortium universities: University of Rio de Janeiro State (UERJ), North Fluminense State University Darcy Ribeiro (UENF) and Federal University of Rio de Janeiro (UFRJ). The CEDERJ Consortium emerged in 2000 as a proposal to form a regional network of distance education. It currently comprises eight public institutions of the State of Rio de Janeiro, with approximately 26.000 students enrolled in its 14 undergraduate distance courses.

2.2 Sample characterization

For this work, we analyzed conceptual maps of 87 students enrolled in the course Instrumentation for Teaching Genetics, representing 63.0% of its total during the year of 2014. The course has Basic Genetics as a prerequisite course. In order to succeed, student must have Academic Performance equal or higher than six, if performance is lower than six, the student is submitted to a final assessment with the totality of contents and should achieve performance score equal or higher than five.

Instrumentation for Teaching Genetics, Cell Biology I, Cell Biology II, Basic Genetics, Molecular Biology and Evolution courses are compulsory in the curriculum of the Bachelor's Degree in Biological Sciences, and offered at the second, third, sixth, seventh and eighth periods respectively. Among the courses listed, only Biotechnology is elective. The frequencies of students, subjects of this research, which have acquainted the courses listed above, are shown in Table 1.

Table 1. Amount and percentage of students that have already taken the courses predicted at the Bachelor´s Degree on Biological Sciences *curriculum*.

Courses (category)	Students number (%)
Cell Biology (compulsory)	87 (100%)
Basic Genetics (compulsory)	87 (100%)
Molecular Biology (compulsory)	47 (54.0%)
Evolution (compulsory)	44 (50.6%)
Biotecnology (elective)	18 (20.7%)

Regarding gender, 83.9 % are female and 16.1 % male. The average age of participants was 32 years old ± 9.1. As for academic performance in Basic Genetics, the average was 6.7 ± 1.1. Of these, 47.8 % had no failures in Genetics and obtained a mean of 6.9 ± 1.3; 15.2 % had failed at least once in Genetics, but subsequently were approved with a mean of 6.5 ± 0. Exclusion criteria: students who were waived from Genetics or missed the first compulsory meeting of the Instrumentation for Teaching Genetics course.

2.3 Data collection and analysis

This paper is a quali/quantitative study. Sample was characterized by data base mining available at the academic registration software of the consortium CEDERJ. Prior concept map building, students attended to a 60 minutes explanation of the procedures. Aspects of the methodology such as its use as a pedagogic tool and the basics elements found in a map were presented. Furthermore, a prototype map was built with a different subject in order to solve any doubts concerning the technique. When this introductory part was accomplished, students were challenged with the focal question '*What do you know about **Genetics**?*' to build the concept map. This exercise was proposed to the students enrolled in the course Instrumentation for Genetics Teaching during the first two mandatory personal meetings, scheduled for the beginning of the period. Students had 30 minutes to perform the conceptual mapping. The maps were scored according to Novak (1998). Both academic performance and the score obtained by the students on the map were normalized.

To create categories, we used the methodology of content analysis (Bardin, 2006), through the technique of semantic categorization. According to the author:

> "The categories are rubrics or classes that meet a group of elements ... under a generic title, this grouping is done due to common characteristics of these elements (p. 117)."

The intensity and direction of a linear relationship between two quantitative variables *x* and *y* were measured statistically by calculating the linear correlation coefficient of Pearson, using Microsoft Office Excel 2007 version. In this analyzes, the observed correlations do not mean causality. The results are shown in the scatter plots. Values, referential to Pearson´s correlation, according to Swiscow (1997, Chapter 11), namely: from 0.00 to 0.19 - absent or very weak; from 0.20 to 0.39 - weak; 0.40 to 0.59 - moderate; 0.60 to 0.79 - strong and from 0.80 to 1.00 - very strong.

3 Results and Discussion

3.1 Analysis of Conceptual Maps

The conceptual mapping done by the students with the focal question 'What do you know about Genetics?' was assessed and maps' scores, according to Novak (1998), ranged from nine (9) to 138 points with an average of 37.4 ± 22.7 points, demonstrating the heterogeneity of students concerning their structure and organization of knowledge. Figure 1a illustrates a conceptual map constructed by the students and Figure 1b, its English version, reproduced in CmapTools® (IHMC, Florida) software.

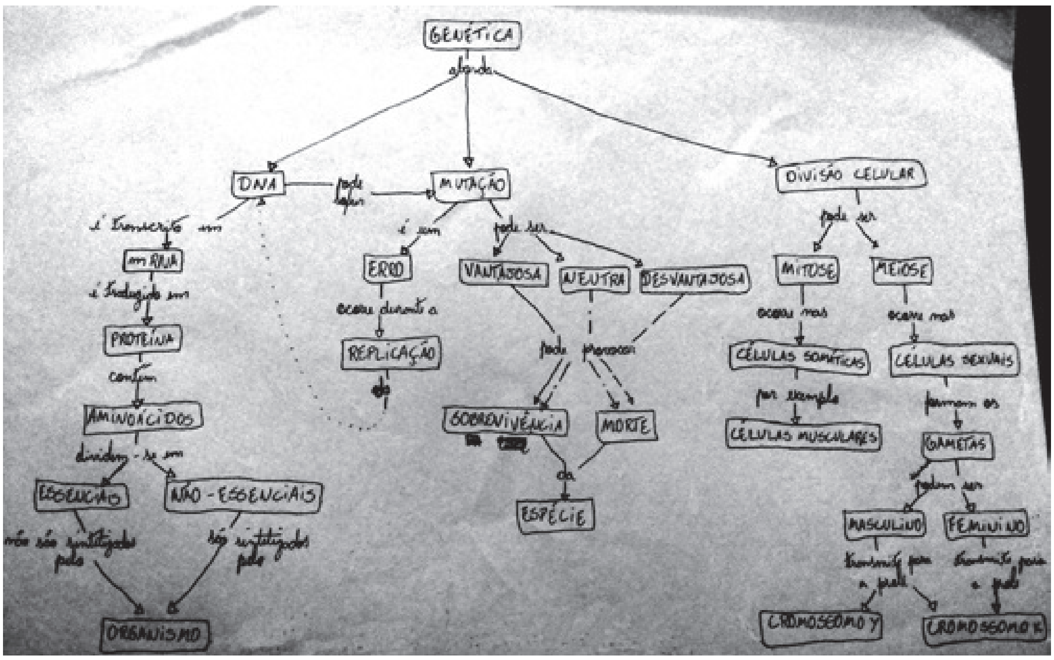

Figure 1a. Conceptual map of one of the students enrolled in the course Instrumentation for Teaching Genetics during the year of 2014.

Figure 1b. Conceptual map of one of the students enrolled in the course Instrumentation for Teaching Genetics during the year of 2014. Reprinted and translated using the CmapTools® software (IHMC, Florida).

The concepts presented in the conceptual maps were categorized by knowledge areas, according to the courses available in the *curriculum* and shown in Table 2.

Table 2. Categorization of concepts present in the conceptual maps of the students enrolled in the course Instrumentation for Teaching Genetics about the focal question *'What do you know about **Genetics**?'*

Categories	(% of students)	Related concepts
Basic Genetics	66.7	Peas Phenotype Gene Genotype Heredity Mendel Variability
Biotechnology	34.5	Stem Cell Technology Transgenics
Molecular Biology	28.7	DNA Proteins RNA
Evolution	21.8	Adaptation Darwin Mutation Natural Selection
Cell Biology	16.1	Nuclear Membrane Chromatin Chromosome Gamete
Total of students	**87**	

Considering the courses of the *curriculum* for obtaining the Bachelor´s Degree in Biological Sciences (see Table 1), it is important to note that all 87 students surveyed had taken the course Basic Genetics, category analyzed with the highest percentage of mapped concepts (Table 2). In contrast, although all students also have already taken Cell Biology course - I and II (Table 1), this was the category with the lowest percentage of concepts set on their maps (Table 2).

The comparison between Tables 1 and 2 shows, in general, the fact that the students have already attended courses whose concepts could be included on their maps, seems to be unrelated to their insertions. These results suggest that, when asked to delineate the concepts related to focal point '*What do you know about **Genetics***?', these students did not attain concepts, more contextual and comprehensive, by including the same in their conceptual models related areas.

We could consider that most recently courses taken by the students such as Basic Genetics, were more likely to have their concepts embedded in conceptual maps of the students surveyed. However, the courses of Molecular Biology and Evolution are also subjects of the last periods, and still do not have their concepts included with expressive representation (28.7% and 21.8%, respectively).

This suggestion of restricted meaningful learning, demonstrated by the inclusion of different topics in their conceptual maps, appears again when we checked the concomitant occurrence of concepts, regardless of whether or not related. In this analysis, 40 students (46.0 %) presented concepts related to only one of the categories listed in Table 2; 28 students (32.2 %) mentioned concepts related to two categories and 12 (13.8 %) mentioned the topics included in three categories. Of the total, only two students (2.3%) mapped concepts of four of them, while no student mentioned concepts of the five categories.

Probably, our results are consistent with the proposition that students often know a lot about a particular concept, however, it may lack a conceptual network that links all the fragments of information available (Campos, Bortoloto and Felicio, 2002). By means, the acquisition of a concept, does not necessarily make it meaningful, a consequence of anchoring process in their prior conceptual model (Ausubel, 2002).

In a more refined analysis, seeking direct correlation among concepts, we reiterate the restricted meaningful learning, since any valid proposition combining concepts from different areas/courses was not observed. This may suggest that although the students include in their maps concepts covered in each of the areas related to the fundamentals of genetics, the learning process proved to be compartmentalized or fragmented by areas of expertise. This seems to be a characteristic of *curricula* that do not work interdisciplinary concepts effectively (Gatti, 2010). Students learn each topic separately, but cannot establish relationships between them.

3.2 Correlation between Conceptual Map and Academic Performance

In Figure 2, the trend line shows that there is a poor correlation between the academic performance in Basic Genetics and the score obtained in the conceptual map (□= 0.2004).

To check the frequency of students showing equilibrium ($\rho = 1$) between academic performance and the map, a straight line with an angle of 45° (dashed line) was drawn passing through the origin. In this analysis, only 13 students (15%) showed very strong results between the scores obtained in the two parameters (Figure 2). A strong correlation is shown in Figure 2 by the points presented nearby the dashed line; these points represent students with convergent score between academic achievement and conceptual map. The furthermost points of the line represent students approaching their significant parameter (Academic achievement – *x* axis, or conceptual - *y* axis), diverging, consequently, of the opposite parameter. It is possible to observe that the "Students focus", below the dashed line, indicate that they have a higher score for academic performance despite the conceptual map, this fact results in a weak correlation between these parameters.

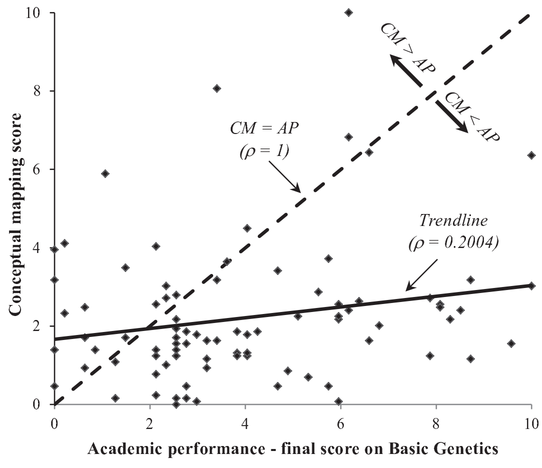

Figure2. Sample dispersion correlating Normalized Academic Performance and Normalized Conception Mapping of the students from the course Instrumentation for Teaching Genetics during the year of 2014.

The establishment of a weak correlation between academic performance and the results of conceptual maps may indicate that traditional assessments based on repetition and memorization do not constitute a suitable approach for measuring students´ "learning" (Medeiros; Bezerra, 2013). It has been a while since studies have demonstrated that conventional tests rarely require more than mechanical learning (Bloom, 1956; Holden, 1992). The knowledge learned mechanically tends to be quickly forgotten, unless they are often repeated. The knowledge structure or cognitive structure of the learner is not enhanced or modified to clarify incorrect ideas. Thus, misconceptions persist and learned knowledge has little or no potential to be used in learning situations and/or resolution of problems in the future (Novak, 2002). Nevertheless, these traditional practices, specifically aimed at classification from short-term memory, seem not to be effective to evaluate the expected skills of the individual in a world where the integration of multiple knowledge is crucial to deal with the amount of available information.

According to our results the conceptual maps analyzed showed quite simple structures – segmented and/or linear, with no conceptual relationship between the different aspects and contexts linked to the focal point.

The concept map can be considered as an assessment strategy of great value once it encourages students to conceptual modeling as a network, providing meaningful learning (Novak, Cañas, 2008).

Thus, inserting the conceptual maps in the conventional assessment system, due to its diagnostic and formative profile, would be a more appropriate strategy. This, not only due to the possibility of measuring conceptual change occurred as a result of the teaching- learning process, but also and mainly for its potential to transform the moment of assessment as a pedagogical practice aimed at meaningful learning.

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