Meaningful learning checking of concepts related to equations and functions in physics chemistry according to the main theme gas law

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Abstract — **In this article, the authors propose an investigation of the learning process of the concepts and of the mathematical relations in the physical chemistry study of the gas, mapping an interdisciplinary teaching approach. The theoretical background of the research is based on the Theory of Meaningful Learning (ML) and on Gowin´s Epistemology trying to relate events, facts and concepts with other elements of knowledge through the "see" heuristic. The research experiments are being conducted with chemistry graduating students at the Universidade Federal de Pelotas in Rio Grande do Sul, during one semester, but it is planned to extend the studies to the engineering courses. The tests to check the subsumers are based on some theoretical questions related to the mathematical concepts already mentioned. Preliminary results of the testing show arithmetic and algebraic disabilities in a percentage of the group, as only 60% of the students answered the tests correctly. Based on the answers analysis contextualized activities are proposed to enrich the mathematics application in chemistry with the objective of favoring the development of the subsumers needed to the comprehension of the PC phenomena studied.**

Keywords- Physical Chemistry, Mathematics, Meaningful Learning, Interdisciplinarity

I. INTRODUCTION

Part of the subjects which composes the specific cycle of the engineering courses and of the chemistry graduation courses need some requirements from the mathematics area (calculus, analytic geometry, linear algebra), as it is the case of physics chemistry. On the other hand, an enormous challenge for the students of these graduation courses is to apply the mathematical concepts that were studied before in an isolated and fragmented manner, in the interpretation of the phenomena related to their area of knowledge.

At Universidade Federal de Pelotas (UFPel) and at Universidade Federal do Rio Grande do Sul (UFRGS), the physics chemistry subject has the characteristic of belonging to the Chemistry filed, but it is also part of the Engineering Courses specifically related to the Chemistry Engineering, Food Engineering and to the Metallurgical Engineering. The aim found in the teaching of this discipline to the Chemistry and/or Chemistry Engineering and to the other engineering courses is that for the first theoretical classes are realized while for the second the classes given are only theoretical. This fact does not allow the complete and adequate contextualization of the mathematical tools causing huge difficulties in their applications.

An optional approach that enriches the practical activities experienced and which has been more present in the graduation courses is related to the use of computer simulation, modeling and virtual reality software among others. The use of computational resources in the education field is related to activities that can potentiate the educational activity and that can add value to the teacher's work as technology and creativity integrate the new format of knowledge transmission. Besides, through the computational activities it is possible to potentiate the cognitive process of the students creating products that put together hypermedia as audio, video, simulations and animations.

In the field of engineering education, we emphasized the research of Zimmer *et al* [1]. Their studies suggest the development of a virtual laboratory of differential and integral calculus in order to contribute for the learning and teaching process in relation to the interest and motivation of students. First, the tutorial software was developed with concepts and definitions capable of solving some differential and integral problems. After, the students presented their works developed in panels during an exposition to the public. Finally, a webpage was created where all the content was organized to be accessible for anyone.

In respect to the teaching of electrical engineering, Vieira Junior & Colvara [12] call the attention to the difficulties that happen due to the huge need of abstraction of the phenomenon studied. This way, they propose the development of some educational software which allows the user to analyze different events of stability in electrical systems.

The authors suggest the use of this software as a helping tool in the teaching process emphasizing the graphics visualization in 3D which allows to put the images and to rotate them showing their view in different perspectives.

Our research tries to comprehend the difficulty of the students through the meaningful learning theory, in relation to mathematical knowledge (subsumers) needed to the study of the gas transformations to propose some software of computational simulation applicable in the physics chemistry subject. The studies were initiated with the realization of a pre-test in order to verify the mathematical knowledge that the students have about: the meaning of an equation, function, its differences and relations, independent and dependent variables, operations about the set of real numbers, quantities directly and inversely proportional and the applicability of mathematics in the chemistry area and, more specifically, in the ideal gas equation in the subject of Physics Chemistry I.

At the same time, interviews with the professors were realized in the Universities mentioned before in this article about the main difficulties found by the students in the applicability of the mathematical concepts. The interviews showed some common difficulties as: in the solving of equations, in the interpretation of inverse quantities, in the representation of functions, among others. One aspect told by the professors is related to the adequacy difficulty of the available graphical software in relation to the aim and needs of the specific subject of Physics Chemistry I.

The initial results of these practical studies indicate the need of developing a graphic simulator for the study of the Ideal Gas Law which will be showed later on this research, after the presentation of the theoretical background. After that the results of the use of the simulator will be presented and discussed and at the end the final considerations will be exposed.

II. TEORETHICAL

The development of the work was based on an investigative study about the learning and teaching process concerned with the Meaningful Learning Theory, its association with Conceptual Maps and the relation between them with Gowin's Epistemology, which are presented below.

A. *Meaningful Learning Theory*

The meaningful learning theory has as its assumption the fact that the student has some knowledge and he can use it as a mean to insert new information into his cognitive structure [5, 9]. According to author [6], the main points of the meaningful learning have as the main actor the student himself who learns when he finds sense in the concept presented and through the conceptual hierarchies which can be understood as the association or combination of new concepts to the ones that already existed before in the cognitive structure.

In the context of this work the concepts about equations and functions acquired by the students will be discussed. From this conceptualization the ideal gas equation will be inserted as the graphical representation of the gas transformations.

The knowledge structures through which the new concepts occur in the meaningful theory [4] sets as subsumers. They act as a support structure to join the new concept forming a new subsumer. The figure below shows this conceptualization.

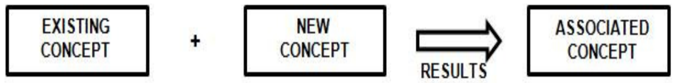

Figure 1. Concepts formation based on the subsumers existency

Source: the authors of this research

The initial process of verifying the meaningful learning consists in the identification of the existence of the subsumers. In this sense, the author [9] suggests the realization of a pre-test to check the existence of the subsumers needed. The pre-test is formed by questions related to the subject which it is intended to be verified and also the level of knowledge that the student has about it.

For the students who do not have subsumers, they are submitted to the advanced organizers, according to the meaningful learning theory. The use of advanced organizers according to author [4] is a way to manipulate the cognitive structure of the student so that he can be able to receive new concepts. The advanced organizers are made of new activities, more elaborated ones so that they can supply the need of the student, affirms the author [9].

B. *Conceptual maps*

In a broad sense, conceptual maps are diagrams that indicate relations between the concepts [11]. The conceptual map establishes the relation among concepts through key words in a non-hierarchical way. The key words can be short linking sentences, verbs, prepositions and also nouns, according to the Figure 2. More specifically, it reflects the conceptual organization of a subject or part of it. In other words, its existence is formed from the conceptual structure of a discipline and it can have two or more dimensions.

Moreira [10] proposes the conceptual maps as useful tools to promote the progressive conceptual differentiation and the integrative reconciliation, concepts present in the meaningful learning theory and he highlights its potential as an evaluation tool over the conceptual knowledge that the student has.

Anastasiou & Alves [8] also suggest the conceptual maps as a strategy of teaching in the classroom. The justification is based on the main thinking operations which allow the interpretation, classification, critics and the organization of conceptual data in a hierarchical manner.

The conceptual maps dimension can be contextualized by classification where dimensional maps tend to present a linear vertical organization giving a broad view of the concepts of a subject. The two dimensional maps, on the contrary, use the vertical and also the horizontality perspective and, therefore, allow a more complete representation of the relations among the concepts of a subject or about a specific aspect.

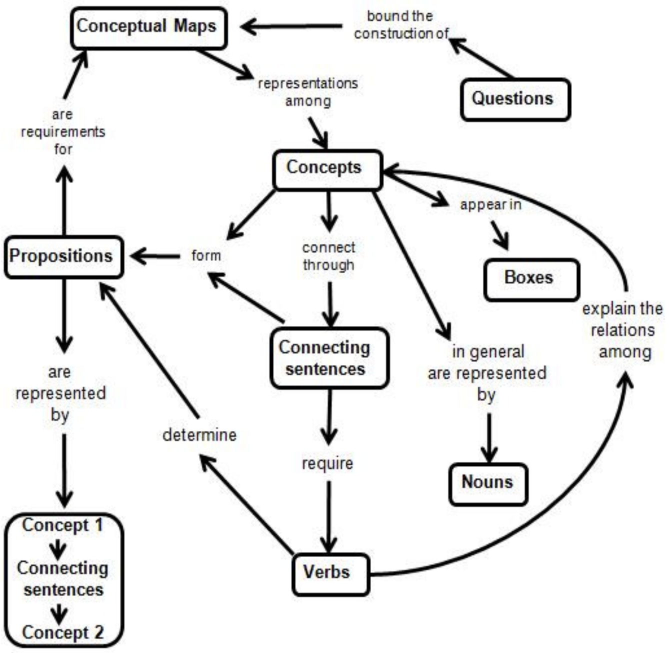

Figure 2. Schematic representation of the relvant aspects of a conceptual map

Source: the authors of this research

In this study, the conceptual maps were used to identify the conceptual domain of the students about the equations and mathematical functions which allowed the evaluation of the level of knowledge of both mathematical concepts. The results showed a simple conceptual map where each student built his own Initial Conceptual Map having as the main point the equation and function from the mathematical point of view. With this, it can be said that the students have different difficulties as to understand the quantities directly and inversely proportional, the meaning of an independent variable, among others.

C. Gowin's Epistemology

The scientific investigation process according to author [2] is the construction of meaning structures from basic elements named as events, objects, facts and concepts. The initial idea is from the observation of a specific event or object which occur in a natural way or is even created by the observer, the procedure of research relates specific relations among the observations of the event done, its consequences derived from the studies of the event, the assertions made by the consequences and the concepts, by the definitions used to interpret, analyze in order to get to the explanation of the event or object.

Concepts are defined according to authors [2] and [3] as signs or symbols that describe regularities in events we use to do in an action as thinking, researching, learning, aiming at finding an answer to the observable events. Conceptual systems are sets of definitions logically connected which allow default reasoning as we relate concepts. For author [3] this fact can signify that the event itself occurs naturally or is caused by the observer or the researcher and it can also be understood as the event registration, or yet, the facts are verbal or mathematical assertions, based on the events registrations.

The research process according to Gowin's perspective is a way to generate signification structures connecting concepts, events and facts. Figure 3 shows this connection in a "v" shape matching events in the bottom to concepts and facts on the sides.

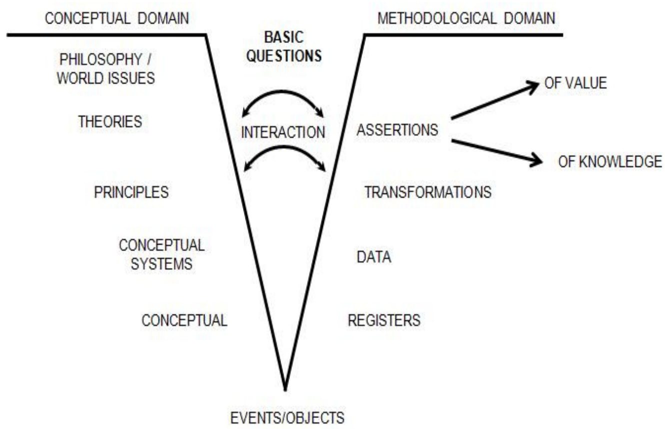

Figure 3. Gowin's epistemology of the 'v'.

Source: Moreira & Buchweitz [10]

The left side refers to concepts and conceptual systems called as conceptual domain of the investigation process where the effective concepts and the conceptual concepts used in the research are situated and generate principles and laws, which also create theories. Value systems, world views and philosophies are related to the theories. In the "v" bottom are the events that happen naturally or that are caused by the researcher in order to obtain registrations through which the phenomena can be studied. Sometimes the phenomenon observed is studied through objects and in this case it can be said that the event is the object itself.

In the case of the knowledge observed in this research that involves mathematics and physics chemistry, the bottom of the 'v' is made of concepts of equations and functions. On the conceptual domain side we have the independent and dependent variables, the quantities directly and inversely proportional, linear and rational function, graphics representation and operations about the set of real numbers. On the other side, on the methodological domain, we have the gas transformations, behavior of an ideal gas, graphical representation with the variables involved in the gas transformation, physics and chemistry analysis and interpretation. The interaction process was realized with the use of the graphical simulator.

The pre-test was constructed in two steps. In a first moment, five theoretical questions were developed about the signified of the content described above, as it can be seen below:

1- What is a mathematical equation?
2- What do you understand as a mathematical function?
3- What is the difference between a function and an equation? Explain it with your own words.
4- Give the definition or explain the meaning of an independent and of a dependent variable.
5- What is the meaning and the purpose of a graphic in mathematics?

In the second step of the pre-test ten questions were created to be answered in an analytical way and eight of them were based on operations involving real numbers and two were described as problems with quantities directly and inversely proportional.

The questions above were answered by twenty students. The result of the first stage showed that most of the students did not answer the five theoretical questions. Two possibilities were raised as possible justifications for this situation:

1º) The students do not understand the concepts;
2º) The students can not express their ideas.

In the second stage of the pre-test ten questions were created to be answered in an analytical way and eight of them were based on operations involving real numbers and two were described as problems with quantities directly and inversely proportional.

Not all the questions in this part were solved by the students. The average of right questions was near 58% (fifty-eight percent) where a higher number was expected.

Through a detailed analysis of the mistakes done, the following were highlighted:

1º) $4/0 = 0$
2º) $2^{-1} = -2$
3º) $3^{1/2}$ = no answer
4º) $x^2 = 36 \Rightarrow x = 6$ (only)
5º) $x^3 = 27 \Rightarrow x = 9$
6º) $\log_2 16 = x \Rightarrow x$ = no answer

In relation to the two problems, part of the students got to the right answer identifying the quantity directly and inversely proportional, but the other part did not get the answer or did not answer the problems. In this last case, among the students that did not do the problems right, most of them chose not to answer the questions.

An initial justification concerning the mistakes of the students is due to the difficulties in understanding or the domain the mathematical conceptualization during his student life, regardless as a high school student or as a graduation one.

Another possibility is that the students find difficulties in subjects like calculation because at most cases they need to take the subject more than once. It also reflects in the low number of students enable to take the discipline of Physics Chemistry I.

Relating it to the meaningful learning theory it can be perceived that the students are owners of some subsumers related to some subjects, as an example, operations with numbers. For those who do not have these, they are exposed to new problems with a different focus to avoid the repetition of activities and to put away the possibility of memorization.

Figure 4. Screen from the graphical simulator used to show an isobarican transformation

III. PRE TEST RESULTS

The pre-test with students of two groups of the Physics Chemistry I subject was realized in the beginning of the second term of 2008 and 2009 to verify the existence of subsumers related to the mathematical functions and equations. It was consisted of expository questions and activities to be solved about the math contents needed to the understanding of the ideal gas Law. The results showed that most of the students have difficulties to apply, analyze and interpret the mathematical concepts used in problems applied in the subject in question. It was quite evident that most of them (between 40% and 50%) do not present the subsumers related to the equations and functions for the Ideal Gas Equation.

Based on the initial results, in the second term of 2008 a decision to work in an interdisciplinary way was taken. For that some monitoring activities of the practical classes in the subject were realized by a mathematics professor. During the laboratories classes the Mathematics and Chemistry professors participated in the process realizing the connections between the two areas in a way to highlight the applicability of the math concepts in chemistry.

Interdisciplinary for author [7] is characterized by a group of disciplines, or areas of related knowledge, which aims at achieving the objective established by one or more coordinators of the process. In this specific case of the ideal gas law the common element is the equation which represents the variables involved in the process as a transformation that occurs in an ideal gas.

The results obtained up to the present moment reinforce the assumptions of the meaningful learning theory. Preliminary surveys of the pre-test showed the identification of the specific subsumers which were worked with the development and application of the Simulator causing the development and post preparation of new concepts insertion for the student.

The mathematical conceptualization needed as a requirement for the Physics Chemistry I Subject more specifically related to the ideal gas Law is potentiated with the use of the simulator. In the graphic representation and in the table which related the variables, the student perceives the concepts of the quantities directly and inversely proportional besides checking the difference between independent and dependent variables. Another relevant aspect would be the representation of specific points delimited by values inserted in the Simulator to express a linear function and a rational function.

The simulator allows the comparison between the first and the following representation demanding the reasoning of the student to identify the position of the following graphic as well as of the third and last graphic.

The use of the simulator also helped the student in the improvement of his initial conceptual map due to concepts seen in the mathematics subjects, as the calculations. New relations among the contents were represented and checked creating a new and more elaborated conceptual map. This shows that the students developed the specific subsumers proving domain over the mathematical concepts in their new cognitive structure. In this case, they are capable of receiving new definitions and information according to author [4].

The mathematical background allows the chemistry professor to relate, with the technical conceptualization seen in the subject, the real gases that behave close to reality in the value numerical ranges of the variables involved in the process.

IV. CONCLUSIONS

The activity of identifying the knowledge acquired and of confronting it with its applicability is not an easy task as it demands the group commitment for those who really search the complete domain of the concept presented by the professor. This raises the critical sense in the students and contributes for their future formation.

In the monitoring process of the learning development done in the classroom it was identified that the students have the capacity to recognize and define problems but they have difficulties in finding the solutions and in realizing the analysis as also the interpretation.

The process of use of the simulator was done by the reception learning according to author [6]. It is expected that the simulator can really contribute with the concepts understandings as it allows the realization of comparisons inside the transformation through three kinds of functions represented in the same space where that variation of the number of mols allows a more effective mathematical analysis. Besides, the independent variables selection permits the same inference and also of the variable that assumes a constant value throughout the process.

The initial and final use of conceptual maps, the last to be developed, can show the evolution of the students in the comprehension of the equations and functions concepts as there is a tendency of specifying and of reorganizing the existing relations in the cognitive structure described before, as well as of the increase in the number of related concepts.

It is also perceived that interdisciplinarity can contribute in a way to organize the thinking and to complement the knowledge acquired improving the general view of the concept taught. So we suggest its applicability inside the Physics Chemistry I Subject as well as in other disciplines that allow the association between mathematics and chemistry.

The simulator use will certainly bring other contributions to the research as well as the increase in the new results found up to this moment. It is intended to improve the interface and the functions of it in a way to create new situations that evolve the study of the real gas and also to follow new groups of Physics Chemistry I groups to obtain a comparison between the groups followed now.

It is intended to do future research to supply some aspects that in this research could not be completed and for that a new research is suggested with differentiated instruments in relation to the ones used up to the present moment.

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