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Differential Calculus and Chemistry: the Challenge of an Interdisciplinary Course

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Abstract

The aim of this work is to describe the project developed, in an interdisciplinary way, between mathematics and chemistry in an undergraduate of chemistry course at Instituto Federal do Rio de Janeiro, campus Duque de Caxias. Since their foundation, the course suffer with the high rates of evasion and failure by the enrolled students. One of the reasons for this problem is the lack of conceptual connection between mathematics and chemistry. Based on this problem, we propose an alternative methodology to relate mathematics and chemistry in a discipline of differential and integral calculus.

1. Introduction

The use of mathematical modeling as a tool to motivate students to study mathematics appear, in Brazil, from seventies. Aristides Camargos Barreto was the pioneer in this practice in engineering courses in Pontifical Catholic University of Rio de Janeiro [1]. From this experience, many teachers started to use mathematical modeling in their classrooms, but without formal registers about their projects or experiences.In fact, the current students have access to a lot of information and use different types of technologies at the same time. And this young students administrate these different things: their study, the use of social networks, to rest and practice a physical activity at the same time. From this scenario, it is necessary that teachers and schools adapt their curriculum, practices and teaching methodologies.In this sense, the teachers seek alternatives to fit the learning challenges to these new student's profile. Therefore, with this goal, mathematical modeling is a strategy to connect real world with knowledge proposed in mathematical classes. The lack of relationship between the mathematical and chemical concepts that are studied in the undergraduate chemistry course are discouragingly factors for students to continue their undergraduate course. We call it evasion (process that the students leave their undergraduate before the end of the course).Apart from evasion, other problem that the undergraduate chemistry course faces is the high failure rate of the students. Many of them credit their failure to difficulties in mathematics in the compulsory subjects in the first year of the course. From this situation, our research aimed study the evasion phenomenon and the failure of students enrolled in the undergraduate degree of chemistry and the relationship with the mathematical teaching. As a strategy to minimize these effects, we choose mathematical modeling to approximate chemistry and mathematics, as Carius at al. [7] described in their work. In Section 2 we discuss the first part of the project, when we applied a questionnaire to evaluate different reasons that contributed for the high evasion rate and high failure of the students. In Section 3 we describe the mathematical modeling process and presented a result obtained along the workshop realized during the calculus classes. We also detail the methodology applied during the subject of differential and integral calculus. At the end, we present the conclusion and final considerations.

2. Discussing the evasion rate and failure of students

Since its foundation, in 2009, the undergraduate chemistry course in Instituto Federal do Rio de Janeiro obtain only 10% to 15 % of the freshmen students formed at the end of the course. The reasons for this problem, informally, are the lack of interest by teaching as future teachers and the great difficulties found by them in exact sciences as mathematics, physics and chemistry. These phenomena is not unique in our group of students. Moura and Silva [3], describe a similar process in an undergraduate degree of geography. Based on this example and considering the informal opinions of our students, the first step of our research was to analyze the profile of the freshmen of undergraduate course of chemistry. With this propose, we elaborate a questionnaire related with

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academic performance of students, their financial and social life. The research was realized with 67 students enrolled in two subjects in the undergraduate course of chemistry: a preliminary Calculus (40 students) and Calculus of one variable (27 students). After answer the questions, we verified that 62,5% of students did not want to study in a undergraduate course of chemistry. Besides, the Instituto Federal do Rio de Janeiro, Campus Duque de Caxias, is not the university that they expected to study. However, the answers related to use of mathematics by teachers of chemistry were disappointing. Most students do not like of mathematics and do not understand the necessity of study mathematics in an undergraduate course of chemistry. As this point of view was common between the students, we note that mathematical modeling was a way to relate these two distinct worlds: mathematics and chemistry. From this scenario, we developed our interdisciplinary project. We believe that, if students can understand the reasons why mathematics is so important in their formation, the evasion rate and failure of students can decrease.

To illustrate the first part of the project, we presented in Figure 1 the answers of the group of preliminary Calculus, with 40 students for the question: "How a chemistry teacher do use mathematics in your activities in a class?"

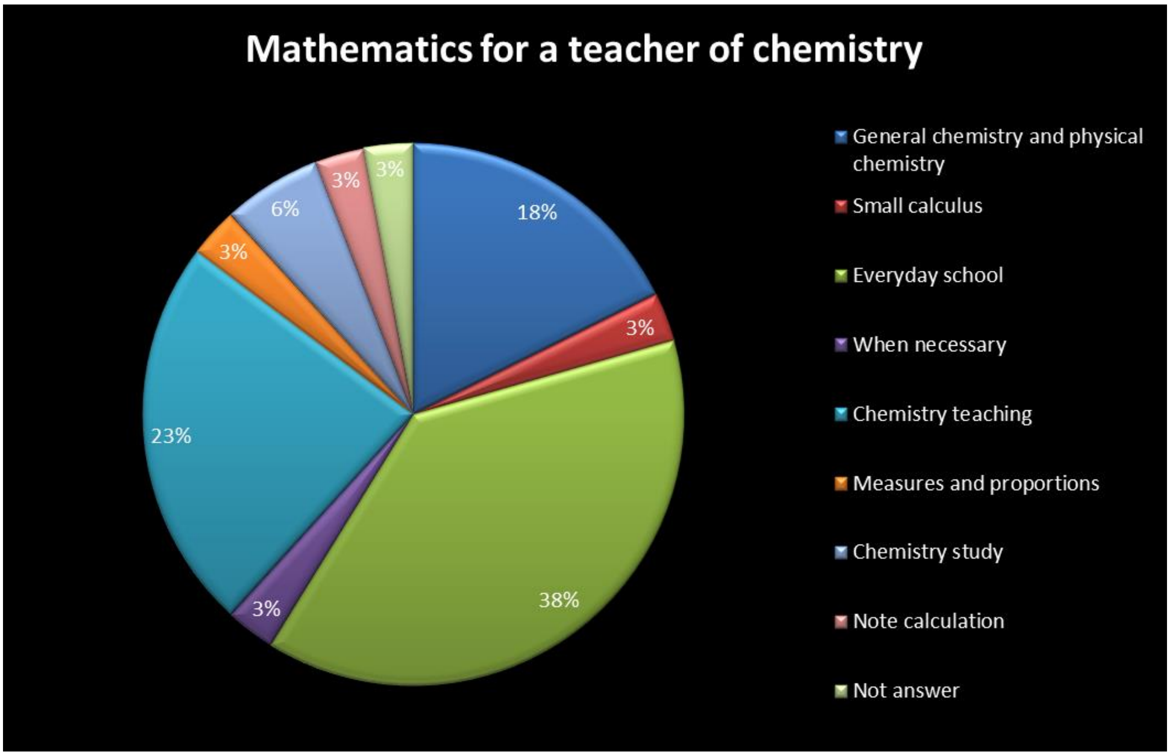

Figure 1: Graph representation for the use of mathematics by a chemistry teacher according to the students.

3. The experience of mathematical modeling in a undergraduate course of chemistry

The term 'mathematical modeling' as a process to describe, develop, model and solve a problem situation in some area of knowledge already finds itself in the early twentieth century literature of Engineering and Economics [1]. The use of the term appears in education studies in the United States in the late fifties and early sixties.From the advances of use of mathematical modeling in classrooms and several contributions both by researchers as teachers, we notice an evolution for the concept of mathematical modeling in teaching. Niss [4] differentiate modeling in two ways: descriptive modeling and prescriptive modeling. According with Stillman et. al [6], descriptive modelling is usually the focus of practice. As our research have as main results of interest those associated with the practice in an academic discipline (Calculus of one variable), we believe that our work is a representative of this type of process of mathematical modeling. It is relevant that mathematical modeling applied to the teaching contribute for the development of these skills in the students. According with Greefrath [2] we describe the sub-competencies involved in modeling as: constructing, simplifying, mathematizing, interpreting, validating and exposing.

The Figure 2 is a schematic model of the modeling process used in our research. Sub-competencies were developed in each step.

According Schmidt and Di Fuccia [5], there are two ways of using mathematical models in chemistry classrooms: mathematical models are used for calculate and in applications using given mathematical models. On the other hand, mathematical models can be created by the learners and used in a process of explaining facts and data in order to solve a chemical problem or to answer a chemical question. We are interested in this type of approach. This process constitutes, for us, **mathematical modeling in chemistry.**

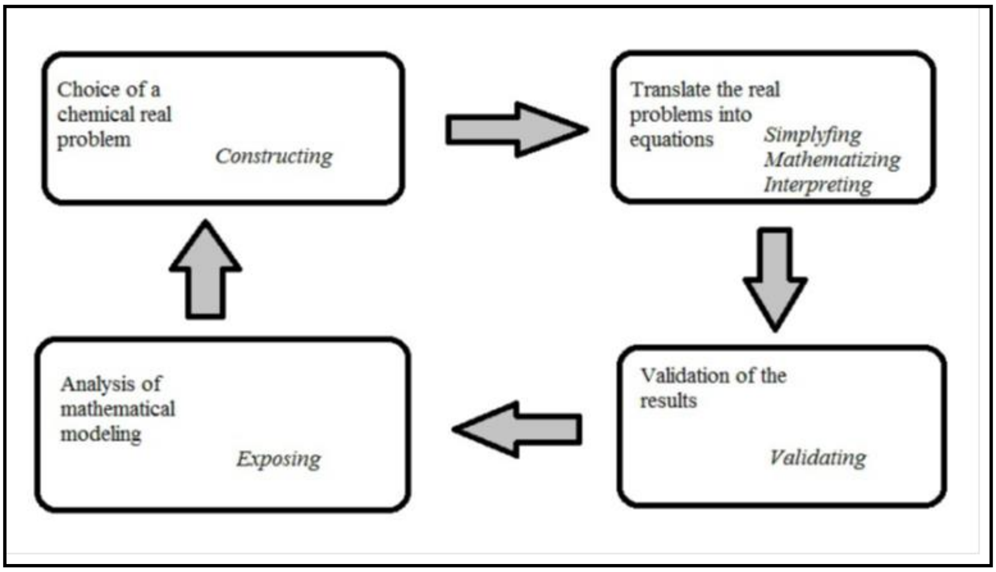

Figure 2: Schematic representation of each stage of our research, including sub-competencies developed in each step.

3.1 An example of mathematical modeling applied to teaching of chemistry

As we may see in the Figure 2, the first step of our process of modeling is the choice of chemical theme. We propose some themes: reaction speed, enthalpy change, molecular entropy, electrochemistry and others. Next, we separated the class into groups with six students. Each group should choose a theme. In this step, the group should analyze the proposed theme, understanding the chemical problem without relation, a priori, with mathematics. Our goal, in this step, was promote the construction of chemical models from the proposed theme. After this first contact with the themes, we presented some problems that involves derivatives and integrals for each theme. A group should study two problems: one related with derivatives and other related with integrals. At follows, we present an example of a problem proposed for a group of students in our classes

At the heart of quantum mechanics is located a paradox: an object such as a photon can exist both as a wave of wavelength and as a particle. A form of de Broglie equation relates the respective values and its mass m

$$\lambda = \sqrt{\frac{h^2}{2\pi m T k_b}}$$

where T is the absolute temperature, h is the Planck's constant and k_b *is the Boltzmann's constant.*

Calculate the derivative $\frac{d\lambda}{dm}$. *Explain the meaning of this derivative.*

At this step, our goal was mathematize the chemical phenomenon, interpreting the constants involved and, in this case, to understand the derivative as a rate of variation. We show at Figure 3 an answer of a group of students for the calculus of derivative $\frac{d\lambda}{dm}$:

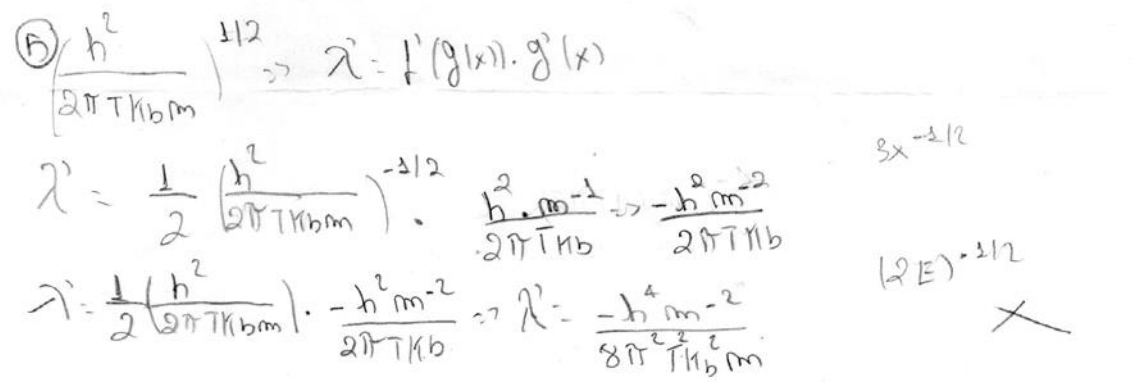

Figure 3: An answer of a group of students for the derivative $\frac{d\lambda}{dm}$.

The follow steps were identifying the role of the derivative $\frac{d\lambda}{dm}$ in this case, and to validate the expression that represents the derivative with experimental data. We may observe in the Figure 2 that the answer is wrong because of the wrong use of chain rule. For us, the students have many difficulties when we change the traditional letters x and y for other variables and they cannot identify the variables and use tools of calculus correctly. Because of it, we believe that is necessary a work including also basic mathematics.

3.2 A new proposal for the course of Calculus

As we introduce mathematical modeling in our classrooms, we may observe that the all teaching learning process should be modified. In this sense, we propose a new dynamic for classrooms and evaluations. The classrooms were divided in two moments: a first part, when the teacher explores mathematics themes, without relationship with chemistry. In the second part, we separate the students in groups with three students and proposed the chemical problems. Then, the students worked with the chemical problem using the mathematical concepts learned in the first part of the lesson. This process was repeated in the 15 lessons of the course. As a consequence of this new process, we modified the evaluation process. Traditionally, we use only written tests for evaluate the students. In this new process, we use three types of tools of evaluation: written tests, weekly workshops and oral presentation. The first of them was individual and the others were in groups where the students could discuss with each other. We observe that this new propose was more interesting and the evasion rate decreased because of it. Although of this decrease, the failure of students did not decrease in the same way. We believe that other factors may contribute for this failure, as a lack of study habit and learning problems in High School related with mathematics and chemistry.

4. Conclusion

After a year of project, we may verify that the evasion rate and failure of students reduced. For the subject 'Calculus of one variable', also in the first semester of 2014, we had 29,2% of evasion rate, 37,5% of failure rate and 33,3% of students were approved. For the first semester of 2015, for the subject 'Calculus of one variable', we had: 3% of evasion rate, 21,9% of failure rate and 75% of students were approved. As we discuss in section 3.2, the evasion rate has a considerable decrease when compared with failure rate. Based on this result, we propose, for future works, new tools to deal with the lack of previous mathematical knowledge provided by High School.

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