A MODEL OF ACTIVE AND SIGNIFICATIVE LEARNING IN THE RESOLUTION OF PROBLEMS

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Abstract
In this paper we present a description and analysis of an activity held in the Mathematics courses in Engineering at the Universidade de Caxias do Sul. The research was planned taking into account requirements for the training of engineers. Analysis of activity indicates that major powers can be developed through active and significative learning strategies. Students who agreed to participate in the activity "Applications of Mathematics in Engineering" show, with their work, opportunities to run, successfully, the path between the "do" and "understand." These skills are related to the steps of the model of active and significative learning, proposed, and are discussed in the analysis of the works presented.

Workshop Topics
Autonomous learning; Beyond active learning; Is learning always evaluable?

I INTRODUCTION

The requirements for the training of engineers in the contemporary form emerge the need for skills related to the achievement of intellectual autonomy, the ability to learn by oneself, learn to learn and deal with problems, being creative and innovative. Our studies indicate that strategies for learning must be focused on the action of the student, together with his colleagues in the study, from the guidance of the teacher. This action must be based on understanding how and with awareness of the process. In the case of learning mathematics, this means understanding the ideas that permeate definitions, rules, formulas and algorithmic procedures; to use the various forms of mathematical expression: algebraic, geometric, numerical and verbal, in the organization of texts themselves, which means knowing correctly read and interpret mathematical texts, producing coherent arguments and justifications for the procedures adopted in the resolution of problems.
In this sense, the action of the student to learn mathematics, must be related to the logic of the development of mathematics, which implies the need for development of skills such as observing, deducing, analyzing, interpreting, comparing, generalizing, proving, arguing, among others. From this perspective, the use of

active and significative learning strategies, has shown many advantages as regards the learning of mathematics in engineering programs. The concept of active and significative learning is to share the very basic principle of who learns by interacting with the environment, with available technology and teaching resources, and with the other actors of the process, teachers and colleagues.

In this work we present and discuss the results of a study involving students of the Math courses in seven Engineering programs at the Universidade de Caxias do Sul, Rio Grande do Sul, Brazil. The study stems from the research project Esimat[1] and had the body of analytical work done by students from a field research in their environment of operation, aiming at the identification of mathematical concepts in real situations of the engineer's actions.

Based on these considerations, we present in the sections that follow: a description of the corpus of study and their context of construction, organization of data obtained from the reading of the work and an analysis of the contents found, to infer on the learning developed. Finally we present some considerations, highlighting the achievements in the mathematics courses for engineering programs, linking them to the model of active and significative learning in the resolution of applied problems.

II THE ACTIVITY PROPOSED AND THE CONTEXT OF CONSTRUCTION

The methodological strategy for carrying out the work, which is the subject of discussion in this paper, consisted of a survey suggested students from Math courses in Engineering programs at the Universidade de Caxias do Sul [9]. The research was proposed to promote the identification of applications of mathematics in the contexts of professional performance of students, whereas they are also workers and many are inserted in businesses operations in the region, considered the second largest Pole Industrial Metal Mechanic from Brazil. By bringing the work to students we justify the possibility of promoting, through the implementation of the research, development of skills needed in the training of engineers. They were encouraged to carry out the research, and informed that for the success of the task proposed would be very important to describe the situation, confronting it with the theory, establishing relationships between reality and concepts discussed, aiming at the identification and possible resolution of a situation-problem of application of Mathematics in Engineering.

The students are organized into groups with up to four components. The conditions for the presentation of work were that it should provide: a clear description of the situation-problem and may be accompanied by tables or graphs in that they could better define and clarify the situation that causes the issue, presentation of the origin the problem, the bibliography of support and identification of people who helped in the preparation, description of how the group worked, explaining how interacted to teamwork; settlement, describing and arguing about all the steps, explaining the mathematical concepts involved; analysis and interpretation of solution providing, in conclusion, to the extent possible, estimates and indicative of alternative ways of dealing with situations such as generating the problem under study. It established a

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1 Teaching strategies and interventions for learning of mathematics in engineering programs - Research supported by the Universidade de Caxias do Sul, since 2005.

schedule for carrying out the work in stages, to assist in organizing the students, since the study was conducted concurrently to develop a mathematics course to engineering program.

Thus, over a semester, students were performing the operations to prepare the work and the studies of the course they were studying. During this period we highlight the interaction between the students involved in the task with the teacher. The fact of proposing a schedule including the submission of work for a first analysis, with sufficient time for improvements suggested, created a movement for greater involvement of students. Many groups have expressed themselves in the classroom or at a distance, looking for clear aspects of the work or make sure about the relevance of ideas and findings that they have found when they searched the sources where they could identify a situation that generating a problem to be presented.

The strategy has been applied since the second semester of 2005 in the Mathematics courses for engineering programs. The works that are the object of analysis in this paper were presented by three groups that are studying differential equations in the year 2008.

III METHODOLOGY

III.1 Analysis descriptors

The descriptors of the items considered in the analysis of the work consists of steps that have been systematized in the form of "metaphor" that we call "spiral" to represent what we present as "a model of active learning and meaningful problem-solving," as in Figure 1. [9]. At each of the papers presented, we looked for evidence of the presence of those items of the spiral in the form of written records which showed what we describe briefly:

1. Observation: demonstration of interest in carrying out the task proposed, with an account of research (conversation, research in books or internet) of situations, from the interaction with the environment of action of the student or the observation of its performance around.
2. Identification: presentation of the generative situation of the problem, the actions employed to identify that, with arguments that justify it, showing consistency between the problem situation and the mathematical concepts presented in the study.
3. Description: presentation of the problem with information enabling the understanding for who is not from the area and also a plan of resolution with sufficient data to estimate a possible resolution.
4. Experimentation: presentation of data obtained through experimentation or available on site for the problem, in most cases, the company where the student performs.
5. Formulation: presentation of the statement with the differential equation model of the problem and the data needed for its resolution, as the methods.
6. Resolution: implementation of the resolution, describing the procedures used to obtain the solution of the problem.
7. Discussion: submission of comments on the solution, taking into account the differential equation model and results.

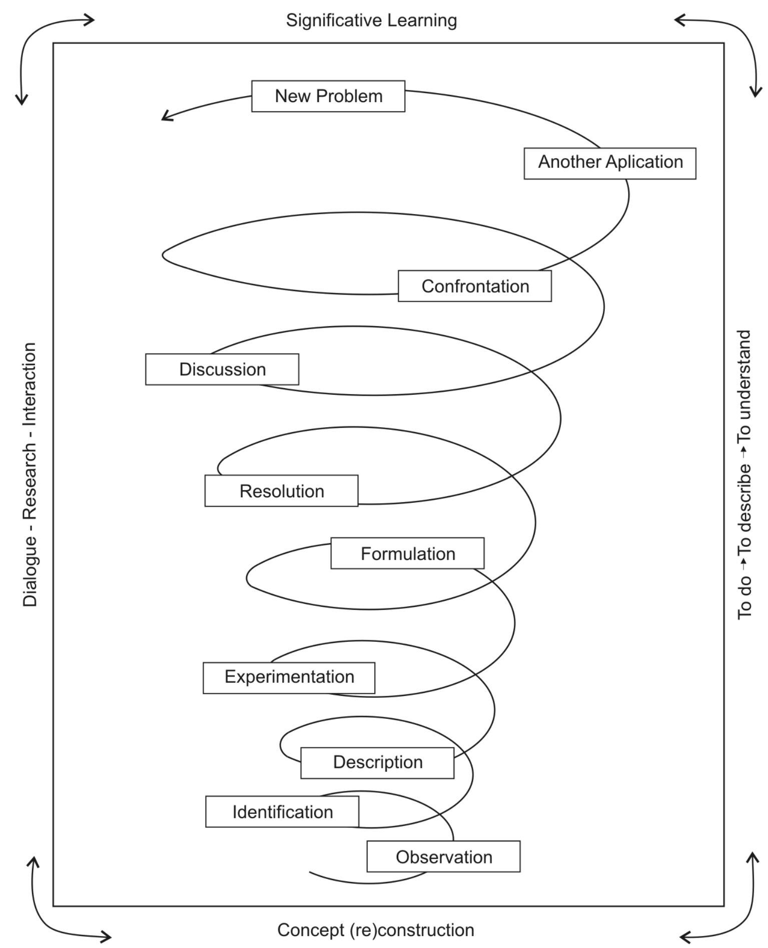

Figure 1. A model of active and significative learning in the resolution of problems

8. Confrontation: assessment of the solution, analyzing it and interpreting it, taking into account the coherence in the context of the situation generating of the problem.
9. Other applications: comments on implementation of the results obtained, by improving or qualifying the situation generating of problem, than can be considered an intervention performed with the results obtained.
10. New problems: records showing that from the situation-problem addressed, arise new problems whose resolution will likely require the same steps.

III.2 Analysis of evidence found

The option was for the analysis of content, in simplified form, to consider what we found in the texts presented. We did this as a way to seek understanding, through inferences and perceptions, if the operations carried out by students, such as statements of problems, its resolutions and other reviews visible in the texts, suggest that they had developed significative learning of the concepts covered. This analysis was conducted in steps: reading of the work to identify the descriptors, as indicator categories of active learning in the theoretical context that we assumed, looking for relationships between these categories to interpret what has been done by students and discussion on the findings, analyzing them and comparing them with the model of active and significative learning in the resolution of problems, proposed by Sauer, Lima and Soares [9].

Thirty nine papers were submitted by 82 students of different Engineering programs: Mechanical, Chemical, Materials, Production, Food and Environmental. Note that the work was not compulsory; it was performed concomitantly to the development of the course. Thus, they represent 59.4% of students enrolled in three courses, whose work has been the object of analysis. Still, we consider important to mention that these three papers were submitted and not accepted, because they were copies. Two of them were copies of works of books and the other was identified as copying the work of a colleague, which was available on the web. We consider important to highlight the lack of involvement of some students with their learning, which is still common in graduate programs. Dealing with this type of conduct, remains a challenge for the teacher committed to high-quality education and situations like this permit us to draw the attention of students on the importance of taking its share of responsibility in the construction of their knowledge. Still, we can say is that many students are learners as subjects in contexts where they do not participate actively in learning, in the sense outlined here. It means they are passive in regards they only fulfill required tasks mechanical and performing mechanical actions to learn mathematical procedures. Some papers were presented with the sole aim of fulfilling the task. In addition, many students, when confronted with tasks such as we propose, would prefer not to get involved.

This explains the number of papers presented on the number of students in each course. Still, the lack of time for many students who are employed may also be one of the variables causing this.

In terms of concepts used, the problems discussed covered, most of differential equations of 1st. order (86.1%). The other had the applications of Laplace transform and ordinary differential equations of 2nd. order, or other applications that did not require the use of differential equations.

The diversity of the situation generating of problems revealed the wealth of the strategy as a way to identify applications of Mathematics in Engineering, particularly in differential equations, and present to the teacher of mathematics for engineering, often alienated from the surrounding applications of concepts taught, the universe of phenomena that can be represented by such concepts.

Certainly this result would be different in areas where students are working in another context. For students of Engineering at the Universidade de Caxias do Sul, as already highlighted, the most work in companies from the Pole Industrial Metal Mechanic, hence the variety of situations generating of problems.

The process of identifying the situation and the elaboration of the problem containing the items requested was rich, both for the teacher as to the student in that it allowed us to identify and overcome difficulties and hence the qualifications of the job. In several cases, at first, the students located in an enterprise scenario containing elements that were related to studying, but could not relate to the observed, with the possibility of modeling, to represent the situation by means of study. In this sense, the dialogue with the teacher, relying on their perception, it was essential to receive tips and problems in order to make possible the establishment of relations between the phenomena described and possible ways of representation, which was extremely enriching for both. In fact, dialogue is an educational strategy enhanced active and significative learning.

The difficulty in other cases was to identify and describe, from a scene of daily life, a problem, its data and what could be constructed, interpreted and confronted. That is why we believe as a prominent factor, the possibility of interaction in order to promote reflection of the student and on this basis, the actions needed for the construction of knowledge. And this requires time to reflect, time to perform, time to understand and to assimilate the new. These operations can provide is that the involvement of students who are motivated. Accordingly the criteria for completion of work, leaving them free to choose whether or not for their implementation, has the function to work for decision making and the development of intellectual autonomy. In fact, when students have to move, interact with the teacher demonstrating value the suggestions received, as can be seen in most of the work presented. Regarding the steps taken as the model being discussed, we believe that the dialogues promoted provided evidence enabled us to confirm if there was “observation”, “identification”, “description”, “experimentation”, “formulation”, “resolution”, “discussion” and “confrontation”.

In fact, the dialogues allow us to identify the path of the scientific method, except the last two steps of the proposed model: “other applications” and “new problems”.

This result led us to review the steps of the model we are proposing, seeking to justify the difficulty of students to "identify new problems" in their daily lives and to create strategies that enable them to develop such skills, considering its importance for the future engineer.

The result of the analysis work is presented in Table 1, where we can observe the impact of levels, for the proposed model.

Table 1: **Impact of steps taken during the resolution of problems**

Stages of model	**% on the total work**
Observation	88,9
Identification	100
Description	83
Experimentation	72,2
Formulation	100
Resolution	94,4
Discussion	75
Confrontation	63,8
Other applications	19,4
New problems	0

The categories are considered items of the model active and significative learning, which we believe are related to skills relevant to the reality of the professional engineer. Through the activities suggested, as it is possible to infer from Table 1, students who were involved showed the significance of the concepts of differential equations, because most of them showed the "formulation" and "resolution" of the problem presented. The item "Discussion of the results," although it had lower frequency than the "resolution" and "formulation" had a good effect, showing that students can, from strategies like this that we analyze, to relate the theoretical results with actual results to situations in your professional environment. We can say that this relationship is forgotten when the learning of mathematics is focused on solving problems in order to get the result, without analyzing or interpreting this result, in the context of situation generating of it. We believe that the strategy for solving problems around the items posted on the spiral model may be a way to encourage students to lead as professional engineers in a critical and independent, able to confront their mathematical knowledge with the phenomena of his daily. For example, during the experimentation, many students had presented, initially, empirical data, mentioning them without proper proof, as if it were possible to "invent data to create a real problem". Still, the item "experimentation" was good attendance and, if so, the students used their desktop to obtain the experimental data, which is highly desirable, so they can see in their environment of operation, discussed in classroom, giving more meaning to learning development. Most of the problems included the identification, formulation and resolution and some have made a comparison between data obtained in the theory with the actual situation, seeking reasons for any differences between these values. In some cases reported research with colleagues in the company, engineers or teachers of courses such as unit operations (Chemical Engineering) or Vibration (Mechanical Engineering) or Machining (Mechanical Engineering), among others. Most of the applications were related to the differential equation model of Newton's Law of Cooling, situations involving heat treatment, drying of parts, machining, cutting to specific means, welding or transportation of food.

In some cases the results were applied in the company, generating financial economy. In any case the students offered new problems. This leads us to rethink on the proposed model, as well as on ways to promote the development of competence related to this proposal. As a possible explanation for this result in particular, we point out the lack of culture for thinking this way, caused by a traditional education that the student lived in, was not required to establish relationships between what is studied and their day to day.

IV FINAL CONSIDERATIONS

Thinking of application of mathematics in the context of Engineering is an opportunity to promote understanding of the interrelationships among mathematics, physics, chemistry and engineering. Accordingly, strategies for active and significative learning provide students to realize that mathematics provides a language or a conceptual tool of great potential for the representation of different types of phenomena and in formulating and solving problems that appear on the day-to-day of Engineering. Thus the proposed model can show that skills can be developed by future engineers, to identify the role of mathematical concepts in the representation of situations in order to produce results of interest through the resolution of problems. The teacher has a role as a prominent promoter of the involvement of the student as much responsible for building their knowledge, motivating him to carry out the work. The reception for the student who is willing to get involved can be demonstrated through guidance, encouraging them to answer questions posted on their ideas in their knowledge.

As to the items of the spiral, which served as a model for the strategy implemented, we believe that they may be related to the steps of the scientific method as Pozo [8] which in turn can be compared to the stages of solving a problem as Polya [7]. In fact, when reviewing this analysis, we face a remarkable parallel, as shown in Table 2.

Table 2: **Scientific method (Pozo) X Resolution of a problem (Polya)**

Phases of scientific method	Phases of the solution of a problem
1. Observation and proposition of the problem	**1.** Understanding the problem
2. Formulation of hypotheses	**2.** Design a plan
3. Planning and execution of experiments	**3.** Implementation of the plan
4. Confrontation of hypotheses	**4.** Analysis of the solution obtained

We observed that the steps presented in the spiral and considered as categories to infer on active and significative learning, are significant steps in the scientific method and should be well explained to students. This can help in the sense that they can to deal with situations in their environment, to relate the actions to understand their reality through concepts they study in their graduation course. Thus they give more meaning to the studies students carry out and can deal with their day-to-day with the conceptual tools learned in their courses.

We also highlight that the items of the spiral can be also compared with the stages of mathematical modeling.

To improve the effectiveness of the proposed activity, we believe it important to present it to students, to deepen the discussion on the steps to be taken, explaining about the significance and importance of each. On improving the model of active and significative learning proposed, we could see that the components that are as steps of a conical spiral upward, not all are necessarily present in the resolution of any problem in the context of the search.

Whereas the analysis of the participation of students throughout the process, we emphasize the importance that future engineers value this kind of activity, recognizing the need to develop skills that allow them with a professional quality to the labor market demands today.

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