PRACTICAL AND THEORY INTEGRATION IN THE ENGINEERING EDUCATION: LABORATORY OF MODELS AND PROTOTYPES

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Abstract: This work intends to relate, discuss and analyze an experience being developed at the Federal University of Rio De Janeiro (UFRJ). Such experience involves the construction of a new didactic model, capable of obtaining a more complete integration between theory and practice and of establishing of a more participative and creative relation of the undergraduate student with the learning process.

The main objectives are to promote the theory and practice synthesis and to develop the students creativity, critical sense and enterprising capacity. The past experiences show that this can be made through a pedagogical conception centered in the actions of the undergraduate students. I.e., the pupil constructs - or reconstructs - the knowledge, resolving problems that are related to the concrete reality and to the professional environment (or area, or field) into which he intends to enter. Moreover, important experiences connected with the teaching of engineering carried through in Brazil during the last years are being discussed. As a base for such discussions were taken the congressional records of the ABENGE - Brazilian Association of Engineering Education that present, every year, a great amount of reports on successful experiences. Such reports usually contain an analysis of the context and of the reasons for which some of these experiences have been institutionalized, while others have been discontinued, no matter their relevance and importance for improving the quality of the teaching of Engineering in Brazil. They also analyze, the enormous successful institutional experiences of the post-graduation centers. These experiences have many of the elements of the new pedagogical paradigm that is being seek, including the tutorial relationship which is built between the students and their supervisors, the search for a thematic unit in the disciplines which are planned in order to prepare the students to carry out the research work necessary to implement their thesis and, finally, the focus on the students. This experience already surpasses the thirty years in the older centers of post-graduation in our country, as the COPPE/UFRJ, which takes care of a great number of students simultaneously.

It is presented and defended here the argument that the education models used with success in the post –graduation courses, as well as the relationship between teacherers and students, can be adapted to the under-graduation courses as long as there are resources, politic decisions and some institutional references that may provide for the construction of new attitudes and relations, and at last, a new culture.

INTRODUCTION

Some of the great problems identified currently in many engineering courses are the fragmentary contents of the disciplines and the disarticulation of the curricular grid. As a result of such fragmentation, we can observe the formation of an academic culture with an extreme emphasis in the presentation of the theoretical aspects associated to the mathematical models of simulation or representation of physical phenomena. This culture is particularly strong in basic disciplines, very important for the formation of any engineer, as Strength of Materials, Fluids Dynamics and Heat Transmission. At the end, this process produced an alienation between practice and theory, concept and phenomenon, science and the real world. Several educators, such as Piagget, Vigotski, Carl Rogers, Anisio Teixeira and Paulo Freire, amongst many others, have shown that the most promising way is the one which transforms the student into the subject of the learning process, that must be understood not as a training for the accomplishment of intellectual tasks, but as a process of knowledge acquisition that is carried through essentially by the work of design, research and the reflection. This new pedagogical paradigm demands the construction of new models of teaching - learning and the redefinition of the roles of professors and undergraduate students, besides new attitudes. Such construction, however, is a long process that passes by experiences, with their effects of demonstration, and by setting of positive results as references for the formation of a new culture.

There are innumerable stories in the literature concerning institutions which have been stimulating the research and the construction of these new models for some decades and have already many positive results to present. New attitudes in face of the process of learning,

in as much on the part of undergraduate students, as on the part of professors, are easily perceivable. So are new models, characterized by a significant increase of the undergraduate student's participation, by the reduction of merely expositive lessons and by the uprising of new relations student-professor, rich in exchanges that occur during the orientation of practical works and become the basic axles of the courses. These new attitudes and relations are so consolidated in some cases that they are no longer seen as new. In Brazil we also have many important experiences. If we take as an example only the congressional records of the ABENGE - Brazilian Association of Education of Engineering, we will find a great amount of reports on successful experiences.

However, the majority of such experiences was carried through in an almost marginal form. They are individual initiatives of isolated professors or small groups. Almost always these experiences end in being discontinued and they are not institutionalized. On the other hand, we have a great institutional experience of success in the post – graduation courses. They have many elements of the new pedagogical paradigm that is searched.

There is an intention to start the construction of some references through the development of a prototype supported by the experiences of some professors carried through in recent years at the UFRJ Engineering School.

METHODOLOGY

The main objective is to overcome the theory - practice alienation and to recuperate the relation between model and phenomenon, in order to assure that undergraduate students will become capable of operating with concepts in the real world for solving problems and surpass challenges.

The basic idea is developed in two plans: one internal in relation to the disciplines, that could be called vertical integration, and the other external, where we will search to integrate the contents of a set of disciplines. In the first plan projects and practical works are carried through with the purpose of surpassing the dichotomy that opposes practical to theory. Besides this works intend to stimulate the critical capacity of the students, as well as its creativity and initiative. The methodology developed involves a series of projects and challenges formulated with the objective of constructing the unit of the concepts and the contents of the disciplines. In the other plan, that can be called horizontal integration, where the integration of the contents of different disciplines is seeked, the construction of a prototype or a reduced scale model will be necessary.

The vertical integration is carried through laboratory works that also involve the design and the construction of reduced models. In this case, the main objective is to stimulate the reconstruction of the unity of the physical phenomena. The projects must be formulated in such a way as to work with all the stages, from the design to the analysis of experimental results and their comparison with theoretical models. These ideas are not original. They are already applied by several schools to surpass the limitations of the traditional education models. The major difficulty is found in formulating the projects and leading the work. As it is an open model, where a total control of the results that will be obtained is not guaranted, this creates some insecurity to people who are using this approach for the first time, teachers and students. This model will demand a great amount of the sensitivity on the part of the teachers, who will need involve themselves deeply with the students' works, but without interfering directly with their choices and decisions. To rise the students to the category of subjects of the learning process, the professors will have to share with them the responsibility for the decisions and involve them in the evaluation of results.

In horizontal integration, the key is the accomplishment of an integrated project, from the conception to the construction of a prototype or reduced model. By doing so, the unit of different disciplines can be reestablished.

For the achievement of these objectives, new interdisciplinary laboratories have been built and alloted to graduation courses, interacting with the research and post –graduation courses like the Structural Models Laboratory as well as the Models and Prototypes Laboratory. The laboratories give experimental support to the study of structures theory, measurement techniques and the behavior of reduced models and structural elements. These activities enclose a large universe of disciplines inside the engineering courses, considering the integration between theory and experimentation. They work conjointly with other laboratories, such as the Computer Science Laboratories of the Graduation and the Small Boats Project and Construction Laboratory.

It is important to emphasize that such labs, mainly directed to graduation activities, appear inside a context where there are already excellent laboratories. They are, however, dedicated exclusively to the research and the post - graduation studies. The Models and Prototypes Laboratory and the Structural Models Laboratory make possible the production of different experimental models for lessons and experimental works and help the students develop the necessary abilities to manufacture models and prototypes. In these labs, undergraduate students learn, in a dynamic and participative form. Those activities helps fixing and integrating concepts and knowledge of different disciplines.

The main contribution of the new labs is to give possibilities to the students to develop their own projects and later on to build them, carrying through

with this effort the synthesis of all the contents of the disciplines involved.
The simple idea of works carried through directly by the students, involving project, manufacture and assembly activities presents a grea potentiality in terms of stimulating the motivation, the initiative, the critical ability and the creativity.

The innumerable examples found in the literature and the UFRJ' own experience show that it is not difficult to reach these objectives if the students are challenged to carry through an attractive task, for wich they have the necessary support, resources and orientation. But to guarantee, in a permanent way, the improvment of education quality, it is essentila that such experience my be consolidated and institutionalized.

Several projects are being developed currently at the UFRJ´ s Engineering School, based on the proposals presented in ths article. Amongst them stands out the experiences described bellow.

INTRODUCTION TO THE NAVAL ENGINEERING DISCIPLINE

This discipline was reformulated with the following structure: during the 1st period the students get to know the different teaching modules through introductory lectures on areas of central interest in the course. These modules have a changeable duration of about 3 weeks. In this case, the main objective, is setting former concepts for the fields of Engineering Design, Building Technology, Machinery and Propulsion, Maritime Transport Structure and Economy. With this aproach, the students will be able to visualize the course structure and of the interconnections among the disciplines as well.

The engineering practice, in this proposition, is planned to be introduced in different levels of depth:
- at a first level, the student is introduced to laboratory practice by manipulating physical models in order to visualize the structures' behavior;
- at an intermediate level, the students investigate the models behavior and establish the relations between theory and practice.
- next, the student builds and tests their own models;
- finally, the student is requested to carry through the project and the construction of a simple boat, as one whaleboat or a caiaque.

These activities give the student the opportunity to acquire a concrete dimension of the contentesthe model representation, facilitating and stimulating the synthesis between the objetc, or phenomenon, and its representation. The student begins to understand the project as an antecipated possibility of solution, and its concrete and material accomplishment, that is translates into the model. In this process, essential aspects for understanding of universe of engeneering are introduced, allowing the students to start constructing the complex and not always evident relations between the project and the resources to develop it.

As soon as this experience is consolidated, there is the intention to institutionalize it, by means of the introduction, in some periods of the naval engineering course, of a supplementary curricular requirement with the name of Integration Project. Working in this project, the student will solve a conjoint of problems that occur normally in a real professional situation.

Project: LABORATORY PRACTICE FOR STRUCTURES BEHAVIOR

The implementation of the Structural Models Laboratory is going on since March 1996. Since this date, laboratory classes have been gradually introduced in different disciplines offered by the Applied Mechanics and Structures Department of the UFRJ Engineering School.

This project involved initially the disciplines of Mechanics and Strength of Materials. Different reasons led to the choice of these disciplines: They were traditionally theoretical disciplines, with a great number of students (about 50 to 60 students in each class) and a high failing average (approximately 40%, in each period). These numbers pointed out to the urgency of a reformulation of the teaching techniques to be used aiming at the improvment of the performance and the students motivation level.

The choosen discipline represent AN interface between basic disciplines and professional ones. The use of new specific pedagogical techniques in this point of the course (3° and 5° periods) represents a strategically intervention with the objective of improving the involvement and the interest of the students.

Finally, it was considered that any improvements introduced in these disciplines would have an great impact on the quality of the courses offered by the UFRJ Engineering School, since they are present in almost all the graduation courses.

The implantation of the project connected with the Laboratory of Structural Models is presenting excellent results. Looking at the development of this project it can be affrmed, after few semestres, that there was a significant increase of the motivation and involvment of the students, besides an improvment in the understanding level and the fixation of theoretical concepts on their part.

HORIZONTAL INTEGRATION

Initially, the horizontal integration is carried through from the disciplines of Rational Mechanics and Resistance of the Materials of the diverse courses of graduation of the Engineering. School. With the consolidation of this first phase, it is possible to extend the methodology wich was applied to other disciplines.

The basic strategy is the accomplishment of diverse projects involving the development of didactic material for the engineering education. This way, the formation of the students involved in the projects is promoted, with basis on the methodology previously presented in this article and, at the same time, it is possible to assemble a collection of didactic material, to be used by the students themselves. This material can also be used by students of other courses and disciplines that are still excluded from this process, and even of other universities.

VERTICAL INTEGRATION

The aim is to carry through the vertical integration of disciplines of a same course and different semesters, starting from the establishment of the connection between practice and theory. The central proposal is to achieve this integration basicaly by means of identical or similar didactic models in different disciplines. In this in case, the basic difference in the approach is the depth level of the theoretical analysis of the physical model. For this, it is also possible to use areas of learning common to disciplines in question, as the Laboratory of Models and Prototypes and of the Laboratory of Resistance of the Materials and Structural Models. Initially, this methodology is being tested in the courses of Civil and Naval Engineering. In the course of Civil Engineering, diverse disciplines from the 3rd to 10th semesters, are involved with this project of vertical integration: Rational mechanics (3rd semester), Elements of Mechanics of the Structures (5th semester), Resistance of Materials I and II (5th and 6th semester), Wooden Structures (6th semester); Steel Structures (8th semester); Analysis of Structures I, II and III (8 Th, 9 Th and 10 Th semester) and Structures of Reinforced Concrete I and II (9th and 10th semester).

In the Naval Engineering course, the efforts are being concentrated initially in the 1st semester, with the disciplines Introduction to Naval Engineering and Graphical Expression, in the 3rd semester, with the discipline Mechanics I and in the 5th semester with the disciplines Naval Architecture I and Strength of the Materials. The projects of horizontal and vertical integration are developed intentionally in a multidisciplinary ambiance, with the participation of professors and undergraduate students of diverse areas and different periods. It is important to emphasize that the great majority of the disciplines involved in these projects had previously an approach that was excessively theoretical. In the disciplines of more advanced periods exists the practice of project, but it did not exist, until this moment, the practice of laboratory.

INTERCHANGES

The projects described above received an extensive support froma great number of professors of the UFRJ and of other institutions as well. The discussions wich involve professors of other institutions have the intention of stimulating implementation of similar projects, taking into account the particularities and differences of each institution. With regard specifically to the projects previously reported, interchanges with professors of different Brazilian Universities are already in progress, as the one with the Fluminense Federal University (UFF), the Military Institute of Engineering (IME) and the Federal University of Juiz De Fora (UFJF).

CONCLUSIONS

The results observed so far indicate that the objectives of the projects mentioned here have been fully reached. In spite of all the deficiencies and the precariousness of the available means, including the lack of equipments, technical staff and material of consumption, a significant increase of the motivation and involvement of the students with the proposed works could be verified. There was also a relevant advance in terms of a better understanding of the theoretical concepts and the capacity of operating with such concepts in the resolution of practical problems proposed during the course.

It is still early for evaluating the long term repercussions in others disciplines of the courses involved in these projects or evenin the external environment of the work market. However, the obtained effect of demonstration has been stimulating the participation of other professors and attracting new partners.

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