DIDACTIC IMPROVEMENT ON A COURSE ABOUT MECHANICS OF STRUCTURES

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Abstract *– The aim of this work is to give a contribution to the identification and analysis of the degree of the Engineering students' learning of the concepts of Mechanics of Structures providing the necessary help for the planning and possible modifications in the organization of the existing courses. The teaching of Engineering over the time was studied, aiming at verifying if any procedures to increase the students' motivation could be recovered from the past. The problems that could eventually concur to the high degree of students' failure in the discipline Strength of Materials taught at Escola Politécnica da Universidade de São Paulo (USP) were raised. The reasons which could lay behind the different degrees of stimulus in the two types of courses have also been studied. Finally the article refers to the planning and adoption of changes made to improve the discipline Strength of Materials by means of the introduction of new strategies for the development of the desirable profile for the engineer. This improvement aims at attaining four characteristics: a solid professional formation, the conscience of being an agent of evolution, the ability to cope with new situations and an ethical consciousness.*

Index Terms – Improvement in the students' motivation, New strategies, techniques and materials to learn Strength of Materials, Teaching mechanics of structures.

INTRODUCTION

At Escola Politécnica da Universidade de São Paulo, there are conventional courses (semester courses), with school periods that are divided in semesters, with registration according to the respective disciplines, and besides them there are also cooperative courses (four-month-courses), serial courses with school periods of a term length and they are named liked that because they alternate periods of activities at school and in companies. We name four-month-course because the period of each modulus in which the academic year is divided in Brazil is a period of four months.

It is important to say that at Escola Politécnica da Universidade de São Paulo the students attend lively explanatory classes for about 30 hours a week. And the usual way of analyzing the capacity of the student to continue his studies is by the tests with grades from zero to 10. He is approved when he obtains more than grade 5.

In this last decade of the twentieth century, we were very restless about the fact that disciplines such as PEF-001 – Strength of Materials, offered to the students in the four-month-courses, and PEF-201 – Strength of Materials V, offered to the students in the semester courses, were being taught exactly the same way as 30 years ago, when we attended the Universidade de São Paulo.

Moreover, in 1994, the results obtained by the students at PEF-201surprised us negatively; then, more than 50% of them didn't pass; so increasing our worry referring to the way the disciplines were being taught.

The experience with the four-month-courses made us become aware about how much a student can learn besides that the professor teaches. At the same time, we were sure that the role of a professor in an engineering school must be greater than being only a source of information.

The professor must help the students place the information hierarchically and organize the knowledge; he must stimulate the youth to create a life project, he must make it possible for the student to have a method of work, he must teach the student the way to work with the knowledge, by creating conditions for the full participation in the society with the exercise of citizenship.

THE TEACHING OF ENGINEERING

The formalization of the teaching of the engineering

Initially, the knowledge was transmitted in the place of work itself, where the craftsmen learned their jobs.

During the Hellenic Period, there was a sign of the teaching of the sciences and the techniques. The Museum of Alexandria which was opened in 342 BC, was conserved for 942 years. The various scientific and technical activities related to this museum and to its renowned library increased the interest for the education in the referred areas.

The masters builder were those who followed the craftsmen; those ones who learned through the experience[1] and those whose secrets were carefully kept and transmitted to the apprentices.

In the 15th century, many technical handbooks appeared. In the beginning of the industrial development, in the 16th century, there was a fast dissemination of knowledge, thanks to which, the printing of books became a reality. The

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16th century also showed the birth of the experimental science.

In 1645, a group of students used to gather regularly at Gresham's College, in London, to discuss Experimental Philosophy, which was the name given to Physics at that time.

In the beginning of the 18th century, the Corps des Ingénieurs du Génie Militaire was created, and in 1740, the École des Ponts et Chaussées was founded.

Thus, from the 16th century to the 19th, occurred the appearance of the Engineering as a profession, showing the importance of the scientific and technical education as a prerequisite for its practice, and a new method of access to the acquisition of advancements of the engineering was introduced: the method of the applied science.

The teaching of engineering was instituted in Brazil by the Real Academy of Artillery, Fortification and Design in the year of 1792.

With Brazil's economics development, and existing a greater demand of engineers, the teaching of Engineering in the civil society, was restructured, being settled then Escola Politécnica do Rio de Janeiro in 1874 and the Escola de Minas de Ouro Preto in 1875.

The Escola Politécnica de São Paulo was created in 1893 and the classes started in 1894.

The evolution of the didactic tools

With the passing of the years, the ways of recording and transmitting the knowledge and of studying and learning changed. The communication that enables learning was always linked to the word, initially spoken and later written. About 500 years ago, it was printed and today it is typed. Just for this fact, the introduction of the computer science in the education is justified, using the present communication elements, as computers and nets.

Two reasons to justify the use of the computer science in education can be mentioned: to prepare this generation of students for the tools that will be important in the future and to make available cognitive jumps in its learning. These cognitive jumps are obtained by the intense use of images and by the interactions with the mathematical models properly created with the use of computer science.

WHAT AND HOW TO IMPROVE

Differences between PEF-001 and PEF-201

By searching in the registers of the Department of Graduation of the Escola Politécnica da USP, referring to the four-month-courses (started in 1989), it was observed that, in PEF-001, from a total of 260 registered students, 259 (99,6%) had been approved. And in the same period from 1990 to 1995, from a total of 3305 registered students in PEF-201 in the semester courses, 1759 (53,2%) had been approved and 1546 (46,8%) had failed because of grade or absence.

Those observations created doubts: what were the causes of those differences between the indexes of approval? Would it be possible to reduce this observed difference?

Eventual causes about the differences in the indexes of approval

Some of the possible reasons for the different results obtained by the students in the four-month-courses in comparison to those in the semester courses can be listed:

- Greater motivation of the student in the four-month-course – This greater motivation in obtaining approval in all the disciplines is the possibility of attending the training modulus. Thus, the student can anticipate his entrance in the work market, receiving then such a way, all the benefits of the independence and of the recognition of a future engineer and citizen.
- Personal discipline and professional discipline developed in a different way - The student's maturity is due to the fact that the students train and get in touch with the enterprises' work routine. In the four-month-courses, there is space for the training modulus without any conflict in relation to the academic part; then, it is scheduled. The training period is always a work position occupied by a student during a term and by a colleague in the other term. The fact of knowing that he will be followed by a colleague or even that he might return to the same training period after this colleague, makes him more responsible. They learn the hierarchy of each enterprise, they learn how to behave, they learn to be disciplined in the planning of their own tasks. In the semester courses, the training period is achieved simultaneously together with the academic part, and the schedule is made by the students himself, who, many times, sacrifices part of the classes. This fact stimulates the student not to accomplish part of his "obligation" with the school, that is to attend the classes. Besides, the fact that student doesn't attend to all the classes, assuming a more passive situation.
- Individualist, interpersonal behavior, in the semester course, and of a team, in the four-month-course – The behavior of a team doesn't occur at semester courses, in which the student is registered by the disciplines and, most of the times, he doesn't attend the classes with his mates, of the ideal group. We call it "ideal group" that one that is suggested by the School, as an concatenation of subjects, that doesn't foresee any reprobation.
- Registrations without validity – Several students register in many disciplines in the semester course, and during the semester, they gave up those ones in which they do not get along so well in the first tests (those ones, which they consider to be the most difficult) or that demand a greater dedication.
- The consequences of failure are different – Another aspect that can be focused as one of the most important for the different results of approval, is that, in the four-

month-courses failure in one subject means failure in the modulus. With this, all the subjects, come to be of the same importance, and even those which are not so interesting for a student in a certain qualification, "they come all together". In the semester courses, although it is suggested that the student attends a determined subject, which is a determined hour schedule, he ends up postponing it, in case there is a difficulty.

- The requisites are accomplished in the four-month-courses – As there is no registration by disciplines and the four-month-course is in a series, the student only registers in a discipline when he is really ready to attend it.

The objectives of the improvement

By comparison, we have verified that the requisites of the profile to be examined at the National Courses Examination are basically the same that are listed in the Curricular Guidelines of the Escola Politécnica and they are confirmed by the enterprises as the desirable ones in a research carried out by Escola Politécnica da Universidade de São Paulo, the Confederation of Industries of the State of São Paulo - CIESP, the Federation of Industries of the State of São Paulo - FIESP and RBF - Systems and Methods of Information.

With a basis on these desired characteristics, our proposal in this research is to improve a course in Mechanics of Structures in its way of being offered.

Some of the requisites that a future engineer must have are of the person itself, and by some way they were exactly the ones that helped him get to a school of Engineering. Others must be acquired with the help of the school and of the professors. And it is always possible to improve these requisites. Even the spatial reasoning, which is the capacity of seeing and reasoning in the three dimensions, abstractly, can be improved.

The operating of numerical problems, the understanding of the order of greatness, the capacity of reading and interpreting graphics and designs, the capacity of solving problems, and mainly, the skills of working in a team, being these ones of communication, self-studying and of continuous improvement with bve for knowledge and the ethical sense, associated to the social responsibility, can all be developed with the help of a suitable school environment.

Believing in this possibility, the achieved proposal of an improvement of a Course of Mechanics of Structures contains activities that try to develop some of these requisites.

EXPERIENCES WITH THE DISCIPLINE STRENGTH OF MATERIALS

The discipline PEF-001 Strength of Materials, offered in the 3rd term (four-month) of 1998 to the students of the 4th academic modulus of the four-month-course of Engineering of Computer Sciences, was chosen to incorporate the changes, which could eventually improve the skills of the students.

Activities

- **Planning and teaching plan** - By considering the planning as a process and, therefore, as a continuous activity, of course, it naturally underwent through some adjustments during the development of the course.
  The characteristics and skills related to the engineer profession, to the laboratories and to the person, were developed by stimulating the use of the Library, of the Internet, of the computer sciences and also by the presentations, the discussions in class and the team works.
  In the field of values and attitudes, the development of responsibility and ethics were stimulated, also by remarking that the job of the engineer can be done trying always to obtain a social and environmental profit. It was insisted that learning never ends and it was stressed about the importance of continued education.
- **Explanatory classes** - Nowadays, a lot has been said about non formal classes to facilitate learning and this could suggest that the explanatory class is fundamental to transmit a systematized information from various sources, to make it accessible the foreign sources or most specialized introduce a topic, to finish a determined subject by a synthesis, to clear up doubts, to stress important topics and to motivate the study of a plot.
- **Use of Dr. Beam's - Visual Mechanics program** - Due to the importance of the role developed by the computer, educational computer programs that enabled the didactic improvement of a course of Mechanics of Structures were searched. The set Visual Mechanics contains a handbook with 150 pages and computer programs specifically developed for teaching: Dr. Beam and Dr. Stress, saved in a CD-ROM. Developed by Gregory R. Miller and Stephen C. Cooper, [2] of the University of Washington, in Seattle, United States of America, they intend to complete the study of the bending of beams and the analysis of stress states. The displaced shapes, shear diagrams and moment diagrams appear as an answer in real time to the application of loading, with a pretty adequate visual treatment.
  According to many authors, including BROHN,[3] the human left brain hemisphere proces ses mostly rational, direct, logical, objective information, while the right one processes the qualitative, intuitive, visual, artistic and subjective information. And, therefore by observing the positive index of Chinese in relation to answers which refer to intuitive answers and questions about the structural behavior in a Research study of the performance of American and Chinese students, this was credited to the fact that in the East people write through graphic symbols while in the West the teaching

of engineering is mostly based on direct, objective and scientific reasoning.

- **Group work** - For the group work it was proposed that each group of at most 4 students presented a project among the following: manufacturing of a physical model for the study of the Strength of the Materials; checking of the structure built by the students in the discipline PCC-118 Design, from the previous semesters, according to CHENG et al.'s description[4]; the writing of a computer program which helped the learning of the discipline or facilitated the calculus. The objectives of this activity were the development of the skill of group work, of consulting the library, of valorization of the responsibility and of the interdisciplinary. This activity is described by NAKAO,[5] in the article presented at COBENGE in 1999, held in Natal.
- **Comparison of the real structures with the models** - In a research carried out by SCHWARK,[6] the students pointed to the means of teaching which should be more used. 54% of them mentioned elucidative images (transparencies, slides, videos); 67% mentioned interactive didactic software; 67% mentioned interpretative technical visits. With the objective of developing the capacity of the student to visualize the basic structural schemes that comprehend the real structures, the following materials and the activities that will be described were developed.
- **Transparencies** -LINDENBERG-NETO and ARÉVALO[7] that when we start teaching Theory of the Structures to the students of Engineering two great challenges occur: how to make the study interesting for the students and how to relate the theory that has been presented in class with the proposed mathematical model used to represent the structures of the real world. One of the ways to get to overcome these challenges is by the visualization of the structures. In the classroom, the structural elements are very few, and a set of transparencies enables to bring other examples to the environment of the classroom. The idea was to make that the students reach the idea of what the structure is and how and why these elements stand. The images of the city of São Paulo itself get closer the objective of the study to the reality of the student. The final objective is to contaminate the student with the curiosity and the need for explanation.
- **Improved models** - Knowing about some existing models to illustrate the phenomena approached by the Strength of the Materials, developed by SANTOS,[8] we were motivated to provide other models similar to those ones or incorporating some improvement on them. One of the improved models is a beam of transversal rectangular section, with printed reticulate checker in its faces to demonstrate the simple flexion, the hypothesis of Navier and the bending. It was built with silicon to mould and with catalyzer RTV 573.
- **Correction of the tests and self-evaluation** - An innovating experience was applied in the correction of the tests. For each student, there was another one who acted as a mirror. In order to make it possible the feed back on the performance of each student and of the class, the correction was made in class, preliminarily by the group of the students itself. At the end of the class, the professor confirmed and corrected the grade that had initially been given. A key section with the criterion of attribution of grades was made, and forming couples, each student corrected a partner's test, consulting the professor in case of doubt. The student who corrected, could only understand the solution of the problem presented by the partner if he accompanied the line of reasoning written and registered. If there was any initial mistake and it went further, the student who corrected, checked if from that point on, the solution was correct.
  With this, all the students had the opportunity of verifying the mistakes made by the partners and also their own mistakes, and they were able to assume themselves not to repeat them again. The time taken by the correction was profited for the learning, for the students who corrected explained the solutions obtained by the partners, their corrections and mistakes. In the idea of a mirror, this strategy allowed them to be aware of their strong and week points, for everyone had the opportunity to discuss and explain why they had attributed that grade to each of the questions.
  They developed the skill of the work in a group, besides the values of responsibility, of ethics, of loyalty to the professor and their partners. And mainly, learning was reached even during the correction. The tests were reviewed by the professor and the complete set of the grades attributed by the students was correct.

CONCLUSIONS

With the conviction that the improvement of teaching methods must never be only a goal in itself but yes an important means for the university to fulfil its social functions, we catch the attention and we share the view of BORDENAVE, PEREIRA,[9] according to which "The modernization of the methods doesn't guarantee for itself that the university comes to integrate in its means with its problems and to influence in the transformation of the society".

The methodology to be proposed to teaching must consider four aspects:

- Historical - Situating the knowledge in the time and the space and establishing a link between the old and the new. The presentation of the classic theory with the mention of the dates of some frames for the understanding of the behavior of structures, which was made with the transparencies, revealed itself efficient.
- Timing - Establishing as a pattern the continuing education continued and the recycling of the knowledge

and the attitudes. Nowadays, the most valuable ability by the companies is the one of working in a group, besides the flexibility to be adapted to new situations.

- Innovating Stimulating the questioning, the discussion and the research. Today, this philosophy is present even in the enterprises. The crossed presentation of the students, the continuous planning, the computer programs, the achievement of practical jobs and the test correction by the student-mirror consider this aspect.
- Contextual - Motivating the students and the professors to attempt the promotion, through its action, the search for the final systems created by Man, which is the improvement of the quality of life. The correct interpretation of the reality and the conscious intervention through the acquired knowledge, will have to modify to improve the exiting conditions. The examples of old and new structures, according to the set of transparencies, the discussions about disasters of engineering or about the needs of infra-structure of the country consider this aspect.

Finally, it can't be forgotten the adequate preparation of the engineer-professor for the exercise of teaching. MASETTO[10] assures that, with the consciousness that the process of learning is the main objective of undergraduate courses, the way to conceive the professional passes through a transformation.

Concluding, in this work, by setting learning by the student as a main objective it was attempted to improve the skills and characteristics considered important by the involved community - the students themselves, the professor-engineers and the managers and directors of the industries. The Curricular Guidelines of Escola Politécnica and the National Courses Examination compiled and formalized these needs of the engineer for the 21th century.

The experiences described and related here and comments of the students[11] showed the success in the adapted methodology and confirm the thesis of the need of improving some of the courses still taught according to models of the formal education, which no more satisfy the present expectations.

REFERENCES

[1] Cowan, H. J. *The master builders*. Malabar, Robert and Krieger, 1985.

[2] Miller, G. R.; Cooper S. C. *Visual Mechanics - beams & stress states*. Boston, PWS Publishing Company, 1998

[3] Brohn, D. M. "A new paradigm for structural engineering". *The Structural Engineer*, v. 70, n. 13, Jul.1992.

[4] Cheng, L. Y.; Petreche, J. R. D.; Santos, E. T.; Ferreira, S. L.; Cardoso, L. R. de A .; Kawano, A "Projeto geométrico de uma ponte no ensino do desenho técnico." *Proceedings of the XXVIth Brazilian Congress on Engineering Education – COBENGE* 98 (in CD-ROM). São Paulo, Associação Brasileira de Ensino de Engenharia, 1998.

[5] Nakao, O. S. "Motivando alunos de Engenharia de Computação para o estudo de fundamentos de Resistência dos Materiais." *Proceedings of the XXVIIth Brazilian Congress on Engineering Education – COBENGE* 99 (in CD-ROM). Natal, Universidade Federal do Rio Grande do Norte e Associação Brasileira de Ensino de Engenharia, 1999.

[6] Schwark, M. P. "Sugestões para um curso intuitivo de teoria das estruturas". São Paulo, 1996. *Dissertação (mestrado).* Escola Politécnica da Universidade de São Paulo. p.21.

[7] Lindenberg Neto, H. and Arévalo, L.A.T. "Using images to teach the beginnings of structural engineering", *Proceedings of the International Conference on Engineering Education – ICEE-98* (in CD-ROM). Rio de Janeiro, Pontifícia Universidade Católica do Rio de Janeiro, 1998.

[8] Santos, J. A . "Sobre a concepção, o projeto, a execução e a utilização de modelos físicos qualitativos na Engenhria das Estruturas." *Dissertação (Mestrado).* Escola Politécnica da Universidade de São Paulo. São Paulo, 1983.

[9] Bordenave, J. D.; Pereira, A . M. *Estratégias de ensino-aprendizagem. Petrópolis*, Vozes, 1995. p.11.

[10] Masetto, M. org. *Docência na Universidade.* Campinas, Papirus, 1998. p.13.

[11] Nakao, O . S. "Aperfeiçoamento didático de um curso de Mecânica das Estruturas." *Dissertação (mestrado)*. Escola Politécnica da Universidade de Sào Paulo. São Paulo, 2000.