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Abstract 530

An Experience In Teaching Structures In Aeronautical, Mechanical And Civil Engineering, Applying The Experimental Methodology

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I. ABSTRACT

The purpose of this paper is to inform the results of applying the Experimental Method to improve teaching in Aeronautical, Mechanical and Civil Structures, at the Universidad Tecnológica Nacional (UTN) and Universidad de Morón, (UM), Buenos Aires, Argentina.

The proposed Experimental Method is framed in Kolb´s Learning Model. We have begun to apply progressively this Method in the Structures courses, of which we are professors.

The use of the Experimental Methodology helps to reorganize student´s knowledge, improving the connections between different concepts in different subjects, and puts them in contact with the resolution of engineering problems that will appear in their future professional activities.

We have also observed that this Method encourages students to deeper researches of the structural problems, thus helping them to achieve higher levels of knowledge as independent thinkers, according to Perry´s Model, with important savings in classroom time.

The Experimental Methodology was initially applied in Aeronautical Estructures at the UTN, and according with the results was expanded to Mechanical and Civil Estructures in the UM.

During 1999 the Argentine Federal Counsel of Deans of Engineering Schools (CONFEDI), adopted a similar criteria of the ABET 2000, in the Manual for Acreditation of Engineering Careers.

Regarding the Laboratories, this Manual recommends that students must acquire aptitudes to: design and improve components, systems and processes, plan and conduct investigations and experiments on their own, analyzing and expounding the results, stressing teamwork, which match the objectives of the Experimental Method.

After three years of progressively applying the Methodology described above, the obtained results, are prosperous and promising.

II. Introduction

At the Universidad Tecnológica Nacional (UTN), Argentina, the Engineering programs had a length of 6 years up to 1995. The UTN underwent a profound modification of its curriculum, and managed to reduce the programs duration to a period of 5 years.

On the specific areas of Aeronautical and Mechanical Structures, the Authors consider that the above-mentioned changes in the programs should have been accompanied by a modification of the traditional teaching methodology as well. Thus, the *Experimental Methodology* was applied in a progressive way that started in 1997, through the development of a Structures Laboratory [1].

The traditional use of the laboratory is transformed within this methodology, as it is now designed to aid problem solving by leaving the proposal and solution of the problem to the student's initiative and creativity, guided by the teacher who helps them find the expected answers. The students must propose and build test models and measuring methods according to the parameters that they consider valuable of measuring. This methodology allows students to be motivated in achieving the solutions, and consequently accomplishing higher degrees of maturity as independent thinkers and creators of future self-knowledge. We consider that the Experimental Methodology can also be applied in other subjects and courses as well as other areas of Engineering.

The following text by Edith Litwin [2] (freely translated from Spanish by the Authors) traces an ideal parallelism of the above-mentioned concepts:
When technology is presented to the students for their disposition, the sought object is to develop individual cognition and aesthetic capacities through the multiplicity of uses that the teacher can make with the group's interactivity. If inside our classrooms we solve authentic problems, that is to say, if we display real problems and generate processes of knowledge-building, we are conscious that the students are acquiring useful and valid wisdom. On the other hand, the creation of new simulation spaces that collide with today's teaching culture makes us reconsider the environments where knowledge is effectively created. To reject the pillar that technology, technological wisdom and technological productions build on student's daily life would make us shift backward unto a learning method that, paradoxically, wouldn't be traditional, but instead, fictional.

The proposed Experimental Methodology is based on the *Modern Theories of Learning for Applied Sciences*, by Kolb [3 & 4].

III. The Experimental Methodology and the ABET 2000

In 1999, based on the U.S.A.'s ABET 2000 (Accreditation Board for Engineering and Technology), Argentina's Educational Ministry adopted a very similar accreditation system which was included in the modifications of the curriculum.

In reference to the ABET 2000's *Criteria Program Outcomes & Assessments*, the Experimental Methodology is particularly suited as it facilitates students to develop many of the abilities required. Such abilities are:

- The ability to apply knowledge of mathematics, science and engineering
- The ability to design and conduct experiments, as well as to analyze and interpret data
- The ability to design a system, component, or process to meet desired needs
- The ability to function on multi-disciplinary teams
- The ability to identify, formulate, and solve engineering problems
- The ability to communicate effectively
- The ability to use the techniques, skills and modern engineering tools necessary for engineering practice

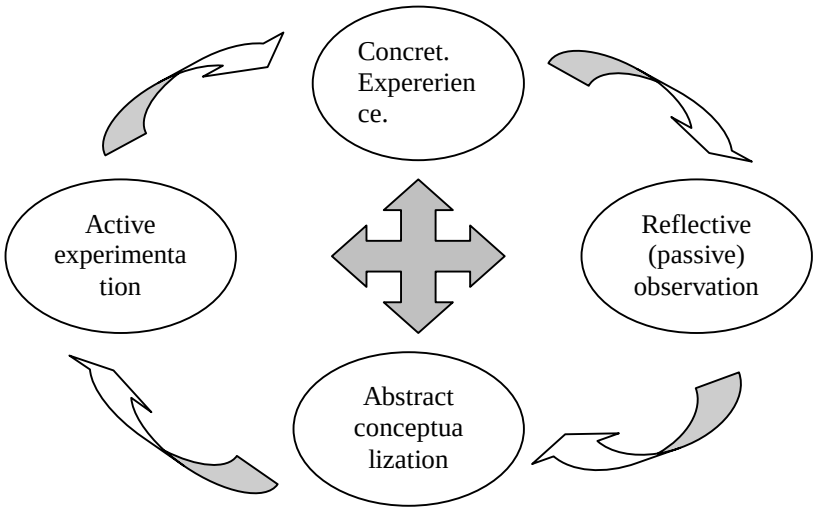
In order to achieve the abilities required by the ABET 2000, the Lab's experimental sequence is organized in a way that allows students to:

- Work in teams
- Previously design the experiments that they will conduct at the Lab
- Build components
- Develop measuring diagrams
- Assemble test components
- Arrange test sequences in logical steps
- Propose required precision of the measurements
- Understand functioning principles of instruments and equipment
- Submit new test proposals
- Use all information sources available (libraries, Internet, etc)
- Keep a detailed record of the experience
- Analyze and evaluate the obtained data
- Write reports

IV. The Experimental Methodology and Kolb's Learning Cycle [3 & 4]

In order to apply the Experimental Methodology, we must follow Kolb's Learning Cycle, which states that for a student to complete the *Learning Cycle*, he is induced to begin with a specific and simple structural problem (*concrete experience stage*). He will try to explain it and design an associated experiment, seeking for related information (*reflective or passive observation stage*). Following this, the student receives the theorical background (*abstract conceptualization stage*), which in most cases is already known to him as a consequence from the previous steps. At last, the student is in condition to discuss the certainty and accuracy of the results that

followed his Lab experience and proposal (*active experimentation stage*), thus completing Kolb's Learning Cycle.



Kolb's Learning Cycle

V. How is the Experimental Methodology applied?

The Experimental Methodology begins by introducing students to real structural problems with basic information and means available at the Lab. It is expected that they design their own experiences and possibly build their own test elements, or propose those that they consider will best suit them.

Professors only participate advising students on how their proposals should be submitted, and discussing them before the students put them in practice at the Lab. Afterward, students receive indications and the formatting instructions that their papers should follow.

Apart from planning their own experience, the students are asked to estimate the measuring scales with which they will be working in order to choose and design measuring techniques and instruments for the applications of force and strain measurement. These magnitudes must be associated with the capacity of the Lab's loading frame, which in many cases imposes several changes on the experiments.

Students should compare the attained results with their estimations to determine the degree of accuracy and validity of their predictions.

The methodology requires students to apply concepts acquired in other subjects as well. They should also acknowledge that there are multiple ways to conduct experiments and that therefore, the best alternative is the one that enables to obtain the best and most accurate results, or the one

that, according to the required precision and instruments available at the Lab, displays the most economical and simple solution.

According to the methodology described so far, the Structures Laboratory has been designed on the assumption that the main user is the student who must develop the habits of observation, experimentation and investigation as the core of his academic formation. The experimental abilities developed by undergraduate students are key elements in the elaboration of a thesis, investigation paper or work as practicing engineers (ABET 2000's abilities).

VI. How is the Experimental Methodology applied in teaching Structures

According to the Structures Laboratory's capabilities, the Experimental Methodology has been progressively applied in the following topics:

- Column stability (short and long columns)
- Measurement of principal stress
- Stress distribution around holes
- Curved beams stress
- Plates and shells stability

As an example we briefly describe an experience: stress distribution around holes.

The students constructed a test model (a plate with a hole) and bonded strain-gages in the model in those places where they considered most convenient in order to verify the stress distribution and concentration in the hole boundary. Afterward, they applied forces to the model and obtained values of strain and stress, analyzed the results and obtained conclusions about the behavior of the model. When the students received the theory of stress distribution they were already prepared and could easily understand the equations as they could relate them to the experiences they had conducted.

We must also consider the added value of the multidisciplinary aspects of the Experimental Methodology [5].

- Team work while conducting the experiments, seeking information and discussing the results
- Writing reports
- Concept of statistical distribution
- Concept of instrument's capabilities used in the experiences
- Concept of resistance, Wheatstone Bridge characteristics, types and characteristics of Strain-Gages, influence of temperature, etc.
- Bonding materials used in Strain-Gages
- Concept of strain and stress, Mohr's Circle.
- Precision and sensibility of measurements
- Data automatic processing possibilities
- Strain-Gage basics for instrument design and construction

VII. Preliminary Evaluation

After three years of applying the Experimental Methodology, the obtained results are favorable, very promising and encourage us to continue working in order to expand its application to other areas of Engineering education, as the advantages of this methodology in contrast with the traditional system of expositive lectures are evident.

The initial success of this innovative method and its positive effects in teaching has impelled the Universidad de Morón to adopt it in its Civil Engineering curriculum. At this University a re-engineering process of all its Laboratories is being conducted in order to carry out the Experimental Methodology in a more extensive way, starting with the junior years of the Engineering programs.

For the evaluation of the Experimental Methodology we have initially considered three parameters:

- Productivity
- Percentage of attendance
- Higher level of knowledge

- **Productivity**

It is measured by the decreasing time needed to teach the same topics compared with the traditional expositive method. For this new Experimental Methodology, we consider the Lab hours as well as the classroom time. The average time reduction has been around 20% (*see Graphic # 1*).

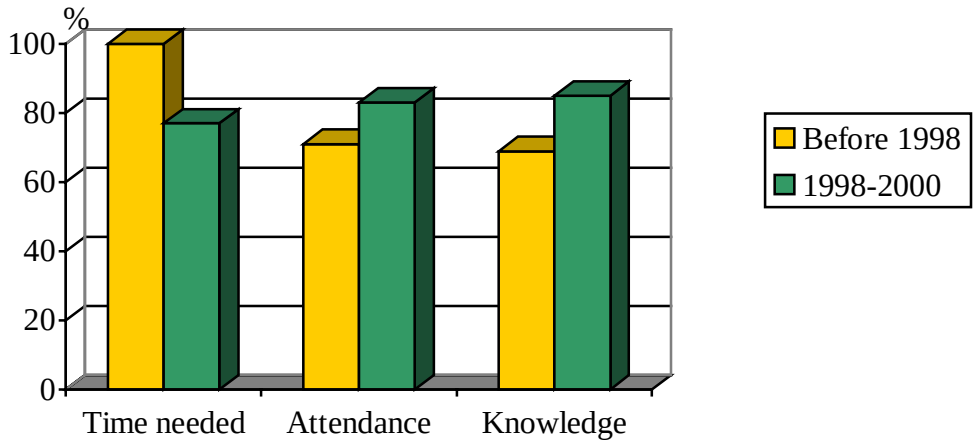
- **Percentage of attendance**

It is easy to understand the attraction and interest that engineering students manifest when they have the possibility of interacting and running tests over structural components. As a result, class attendance increases significantly, and we become receivers not only of the active attention from our class's team members, but also from additional students from other courses attracted by comments and the possibility of performing solid experiences related to the engineering world.

- **Higher level of knowledge**

The grading and approval scales in Argentine Universities differ from those used in USA. Explaining the two methods is an issue that exceeds this paper, so we have considered the approving grades on partial exams, in order to accomplish this preliminary evaluation of the Experimental Methodology. It should be taken into account that this new methodology requires a modification of the tests given, due to the improved and superior level of knowledge of the students at the time of their evaluation [6].

Graphic # 1: Preliminary Evaluation of the Experimental Methodology



Factors considered

- **Stability of long columns (elastic period)**

Period	Time Needed (%)	Attendance (%)	Knowledge (%)
Before 1998	100	71	67
1998-2000	83	84	79

- **Stability of short columns (plastic period)**

Period	Time Needed (%)	Attendance (%)	Knowledge (%)
Before 1998	100	68	62
1998-2000	79	79	81

- **Curved beam stress**

Period	Time Needed (%)	Attendance (%)	Knowledge (%)
Before 1998	100	73	76
1998-2000	75	82	92

- **Stress distribution around holes**

Period	Time Needed (%)	Attendance (%)	Knowledge (%)
Before 1998	100	71	67
1998-2000	83	84	79

VIII. Comments about the qualitative evaluation of the levels of knowledge and maturity according to Perry's Model [6]

Even though this is the most important aspect of evaluation, it is also the most difficult to assess. An idea of the degree of the student's maturity and evolution can be deduced by their questions and report comments, or when they suggest new ideas, experiences or methods for performing and analyzing the results.

We are currently studying an evaluation that consists of two parts:

1. Through tests featuring open problems with answers of various degree of accuracy and application
2. Personal interviews related with the results of the above-mentioned tests.

However, we have not yet obtained enough experiences and data.

IX. Conclusions

After tree years of experience there is no doubt that the application of the proposed Experimental Methodology manifests important benefits due to a reduction on learning times, increasing the levels of student's interest and improving class attendance and course completion, as well as additional qualitative advantages over the traditional Engineering teaching methods.

This Methodology enables students to adopt a working method related to their future professional activities, and is therefore particularly suited to achieve the abilities requested by the ABET 2000

According to the multidisciplinary characteristics demanded by the Experimental Methodology, its extension to other areas of the Engineering education, starting from the junior years, is highly recommended.

It is also necessary to continue studying and researching for methods to evaluate the influence of the Experimental Methodology over the student's maturity levels, according to Perry's Model.

As a corolary, the advances in technology should be applied to introduce changes in the Engineering's teaching and learning methods.

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