INTEGRATING MATHEMATICS TECHNOLOGY WITH MECHANICAL ENGINEERING CURRICULUM

Alicia Tinnirello, Eduardo Gago

Universidad Tecnológica Nacional (ARGENTINA)

Abstract

The curricula of the Mechanical Engineering programs at our university include Advance Calculus at the third year of the engineering studies; the authors’ experience is that students increase their interest and their appreciation for the contents when they are involved by learning it in an applied way. With the objective to carry out these changes, we need to align the university curricula not only to the new work methods that allow intellectual development stimulation, but also to a multidisciplinary approach. This paper presents an analysis and discussion in teaching and learning environments about the integration of mathematics technology into engineering study course with the purpose to reach the competencies, knowledge and skills required in Engineering Education. The effect of mathematical technology on education seems to be greater in Mathematics than in other subjects. Academic education of professional processes is challenged by necessary balance of practical activities with academic reflection. We address this issue by discussing our experiences teaching mathematics and the continuous improvement applied in the Mechanics Department The key objective of this research is to identify barriers to deep mathematical understanding among engineering undergraduates and the access to technology tools and how changed the curriculum content using technology. Engineering faculty assume that certain concepts are taught in the mathematics courses, but they are often not familiar with the specifics of the mathematics curriculum, or the methods utilized (for example: terminology and context of use). Diagnostics have been performed by different instruments applied and were identified problematics areas and specifics difficulties to integrate technology, mathematics and engineering science. The final objective of this research is to develop a model of curriculum integration adequate at the environment work in our University.

Keywords: Learning technology, research projects, multidisciplinary, engineering integration.

1 INTRODUCTION

New technologies are based on complex algorithms that manage to produce, through the use of appropriate technologies, works with unexpected complexity 20 years ago. These algorithms have a strong mathematical basis and allow conceptualize other working methods capable of solving the problems in the practice of engineering.

The study of this new mathematic required deepen and broadening the field of knowledge. To achieve the analysis and utilization of complex design systems and generate experimental non-linear models, the contributions of the new math will be critical, both in the stage of formation of the engineer and his professional life [1].

The engineer must use during the exercise of their professional activity, primarily the reasoning, in order to understand and solve problems with great logical components. It is therefore necessary to focus learning on the development of processes that give the future engineer the possibility to achieve intellectual autonomy.

Many of difficult treatment problems are multidisciplinary, including socio-economic aspects, sciences, and engineering; they involve a large number of components, making them inherently complex. Engineering undergraduate teaching should be appropriately structured to face these challenges.

Curricular innovations should include multidisciplinary aspects, emphasizing the points of view of systems, and introduce engineering problems, principles, practices, and solutions from very early in the career. There is a need to link horizontal and vertical courses by engineering problems [2].

2 THE MECHANICAL ENGINEERING PROGRAM

The structure of the existing curriculum, with subjects per year, is organized in a trunk integrator of subjects up and in a horizontal system of correlated subjects, so that students can integrate
The current curriculum is organized into four interrelated blocks: Basic Science, Basic Technologies, Applied Technologies and Complementary Materials, being aimed at the training of professionals for two levels of hierarchy according to the context of Argentina.

The first application includes tasks for use and operation of consolidated technologies. The second, development, involves tasks at the highest technical level with use of advanced technologies for which professionals must be able to address project, design, research, development and technical innovation. The career offers the possibility of electives subjects, in two areas, Design and Thermomechanics in the fourth and fifth level respectively.


3 THE EMERGENCE OF TECHNOLOGY: MATHEMATICS EDUCATION

Different works describe the various innovative experiences implemented in the classrooms of Advanced Calculus, the career of mechanical engineering, where mediation between the content of the subject and responses expected from the student group, was given through the gradual incorporation, in the dictation or workshops classes, different technological applications (Mathematica, LabVIEW, Comsol) and the use of virtual learning platforms.

Last years, have been implemented methodological strategies with different characteristics, the activities and results achieved have being integrated as contributions made to the training in engineering.

Educational interventions were developed by using technological applications available to explore concepts of modeling, estimation of parameters, numerical simulation and case analysis, pursuing better understanding of concepts and procedures.

Besides, the results achieved by the students were emphasis after using technological applications to validate, verify properties, classify or perform complicated calculations in different subjects, (complex variable function, Laplace transform, Series and Fourier Transform) [3].

4 CHANGES AT THE CURRICULUM CONTENT

The University curriculum reform was based, among the following issues: The need to strengthen and enhance the graduate profile, in accordance with the requirements of knowledge and skills demanded by the society; and in addition, to guide the methodological approach of the programs toward a new kind of teaching [4].

In this context, the Engineering Federal Council projects a curricula reform. The most relevant changes of the proposal are: Train engineers with a general formation, balanced between scientific, technological, management and humanist aspects. Following these changes, the Superior Council of the Technological University approved by resolution of the Board of Governors a New Curriculum Design.
Among the significant changes in the New Curriculum Design are the reduction of the curricula of engineering careers that go from 6 to 5 years of nominal duration; the commitment with the need to achieve a strong student training in basic cycle of engineering careers; to homogenize the knowledge; to make changes in the subjects content in basic cycle; and to introduce the computational tools in teaching, to the realization of practical work of all subjects in the area of Mathematics [5].

Use of technology made it possible to make more explicit the role of modes of representation. In particular, the way in which the complementarity between graphic, numerical and symbolic representation, produce best comprehension using technology and help develop coordination processes.

Thus, the descriptions of the construction process followed by students have allowed relating aspects of the particularization to the reflective abstraction derived from the modes of representation in construction knowledge. These early educational experiences continued with intervention and interaction activities with students, inside and outside the laboratory, through virtual platforms, always favoring the approach and requests.

The use of ICTs in general, relied on the publication of information in sites accessible over the Internet, so that students are acquiring skills of search and self-information and different forms of access; the distribution of some materials for study and report generalized; a communication space was developed on an educational platform and these means, management, planning and monitoring the course, enabling information in exchange forums.

5 IDENTIFYING DIFFICULTIES AND BARRIERS

Learning tasks should approximate in some way to the approach of the complexity requirements, leading to subversion when required, the simplicity in the thinking of the student and its application into practice; not a simple debate or practical exercise, it is studying the teaching process by specifying the mechanisms and mindsets established in order to locate where do make a change [5].

Sciences of complexity explore spaces, open horizons and anticipate processes, phenomena and dynamics, it is in this sense that the use of modeling and simulation reveals essential to explore models, solutions space, with crosses among them, for the study of behaviors characterized by instability, uncertainty, adaptation, non-linearity.

To analyze the profile of the entrants to the career and to take into account the performance in the University seminar, we arrived at the conclusion that the students were admitted to the University with low levels in certain competitions such as ability to abstraction and analytical thinking, among others.

A diagnostic study was developed to measure levels of mathematical knowledge gained in previous years perceived by Advanced Calculus Engineering students. The Mathematical knowledge search consisted of five dimensions: Integration, Differentiation, General subject, Graphics and Limit, related to subject of Mathematics curriculum [4], [5], [6].

There was a very significant difference between the students that successfully have completed the Mathematical Analysis I, Mathematical Analysis II courses during the 1st two years of the careers and those failing those courses. To solve the difficulties to understand concepts view in previous years, practical sessions were implemented at the beginning of Advance Calculus where several applications were showed through special material referred to modeling physical systems and to explain the significant of different mathematical tools in engineering.

6 INTERACTIVE/VIRTUAL LEARNING ENVIRONMENTS

What would an ideal class, adjusted to these changes? When the class is developed in an atmosphere of construction knowledge, the virtual lab plays a key role in this new model of teaching and learning. The introduction of software in problem solving processes influences on the sequencing of the steps which are considered and the criteria which are built for such resolution.

Computer-based education allows us to develop skills in students promoting critical thinking, facilitating the interpretation and limitations of the theory, i.e. experimental study thus prepares students for professional challenges where these tools play an essential role in the Industry.

The designed activities were focused to incorporate various strategies such as: Simulated signals generated in physical systems due to functions of one or more variables representing characteristics
or behavior of any physical process, systems modeling as devices that are responsible for transforming the signals responses producing others or any desired result, as well as build and develop skills in management methodologies and mathematical tools for signals treatment in continuous and discrete time systems, in the temporary or frequency field, deterministic or stochastic.

Identified strategies are designed to develop skills in students to adopt a style of active learning that favors the ability to deal with risks and a competent behavior to deal with difficult situations, for example, requiring discover solutions, manage conflicts, give feedback and learn to delegate.

Modeling and simulation are, require or imply mathematical formalization (previous) work, but this is not always true, sometimes the mathematization can be done later as a verification or demonstration of what has been modeled or simulated. It is necessary to consider that simulation and modelling demand prior work, conceptual or theoretical, that leads to analyze algorithmic or computational problems.

7 ADVANCE CALCULUS AND APPLICATIONS

Examples of assignment work and computer projects

7.1 Modeling and simulation of mathematical tools used for faults in bearings

We analyzed the different existing methods oriented to the study of failures in mechanical systems through spectral and temporal models: Waveform Graphics and spectra using the FFT analysis.

The methodology used was: Create signals by means of simulated data, presentation of the wave patterns and the corresponding spectrum, addition of stochastic noise from generators, spectral analysis of signals with noise and presentation of parametric models [7].

It was investigated on the different types of spectral frequency characteristic of failures such as: imbalance, misalignment, looseness, friction between moving parts, failure of bearings, problems in the engagement of a couple teeth, rotors of electric motors with broken or defective bars, etc. also was interpreted the influence of the phenomenon of resonance in the spectrum of frequencies.

We provide an activity to the students to deal with real problems through simulation and perform a statistical analysis of data by using the technological tools to integrate the knowledge of the calculation of probabilities and dynamic models and apply it to real processes.

Dynamically signals were simulated for the study of vibrations in rotating equipment, to display different analysis techniques and mathematical models involved. Patterns of different signs were analyzed to incorporate prior knowledge about the behavior of the mechanical systems operating in theoretical conditions of functioning. Simulated signals were compared with the real signals, checking the signals with the patterns when noise is added that disturb the output vibration signal.

They simulate signals with and without noise, the noise was incorporated by stochastic generators. This procedure provides a more realistic estimate signal which can deal with the ones that show the measuring equipment, allowing a more genuine comparison of the graphics information that they provide.

The results of these works are shown below:

a) Patterns of behavior of a signal of a gear with wear, sine wave and equation mixture of harmonics without and with noise, Fig 1, Fig. 2.

\[ f(t) = \sum_{n=0}^{N} A_n \text{Sen} \left( 2\pi n f_c t + \varphi_n \right) \quad f_c = f_c N \]  

(1)

being \( \varphi_n \) phase angle and \( N \) number of gear teeth [3], [8].
b) Axis of rotation slide: Equation of sine wave with changes in frequency amplitude

\[ f(t) = \sum_{n=0}^{\infty} A_n \sin(2\pi n f_r t) + \phi_n + \sum_{j=1}^{\infty} A_j \sin(2\pi j f_r t) + \phi_j \quad f_r = f_r N \]  

(2)

being \( \phi_j \), phase angle and \( A_j \) the j-th harmonic amplitude [3].
7.2 Failures that occur in an induction motor: Simulation of an electrical signal

The objective is the signal analysis rather than the techniques of data acquisition and LabVIEW is used as a platform for simulation. Through the front panel students watch the simulation perform by the analysis of the simulated signal coming from the engine, illustrated in Fig.7:

Since the student interest is focused on signal analysis, rather than technical data acquisition, and considering that LabVIEW was choosing as a deployment platform intentionally, it facilitates the acquisition, signal conditioning and testing the signals stored [9].

Fig. 9 was analyzed to detect faults in motors provided with increasing engine load, since the higher load produce lower speed, greater the slip, resulting in more distance between the fundamental harmonic frequencies and those located in the sidebands, and therefore easier to distinguish failures. Therefore was concluded that diagnosis of faults is performed with the engine load close to the nominal [10], [11].

![Fig. 9. Damaged engine: temporary response and frequency spectrum.](image)

In Fig. 10, students observe current peaks at frequencies of 60Hz, and 63,33Hz 56,67Hz, corresponding to the fundamental frequency and the sidebands matches with those expressed in previously works. The difference between the highest peaks of the sidebands and the fundamental is 19,22dB, which means that the engine has severe damage in the rotor [12], [13].

![Figure10. Test report of a motor damaged](image)

### 7.3 Design of an air heater, simulation and modeling with COMSOL Multiphysics

The problem presented here is the design of heat transmission equipment development in a laboratory class as an example task for mechanical engineering.

It was very interesting the treatment in the class of this engineering application as the air heaters are an interesting option to increase the performance of the cycle responsible for generating steam.

The project consists in the air heater design, where the fluid enters from the top and comes in contact in descending order with the gas pipes of heat transmission, which are placed in the form of a labyrinth, the design allows the contact of the air with pipes across its surface, while the air outlet is located at the bottom.

Students work with the Comsol Multiphysics simulation platform that represents through their interactions what happens with the fluid when it's exposed to different conditions of work.

Specifically, technology used is CFD (Computational Fluid Dynamics) of COMSOL. This module is designed for the solution and simulation of fluid flow problems ranging from a single stage laminar flow
to a turbulent flow and the resolution of problems of heat transfer, either by conduction, convection or radiation [14].

This module includes numerical methods and algorithms to replace the systems of partial differential equations in algebraic systems equations to solve using a computer [10].

The work carried out can be seen in Fig.11 (a), where it is displayed how the temperature varies while the air enter in contact with the tubes, while in Fig.11 (b) indicated by a temperature graph characteristic points in the design equipment. In Fig. 12 is observed another simulation to increase the temperature to 60°C studying air temperature of the outgoing air.

![Figure 11. Temperature variation $T_0 = 25 \, ^\circ C$](image)

![Figure 12. Temperature variation $T_0 = 60 \, ^\circ C$](image)

It was also discussed, the variation of the speed of the fluid, Fig. 13, and the increase with the increase of temperature. The simulation design allows perform a real analysis of the pressures, variation of density, internal energy, etc. These are other features that can lead to an optimization of fluid flow analysis [15], [16].

![Figure 13. Velocity variations. $V_0 = 17.5 \, m/s$](image)
Using Comsol showed the importance of technologies implementation to study the main phenomena that occur in the nature of fluids flow and the heat transmission, in a particular context. The simulation results it can clarify in what way it behaves a fluid exposed to different conditions and analyze the full behavior of the same in its path. It follows that the use of the virtual platform streamlines the study of physical phenomena, contrasting the methods used to verify the experimental results.

8 CONCLUSIONS

The teaching activity based on these types of integration discipline allows the concepts, theoretical frameworks, procedures and other elements with which they have to work with teachers and students are organized around units more global, conceptual and methodological structures shared by several disciplines. The academic activities of integration discipline contribute to the consolidation of certain values in teachers and students: flexibility, trust, patience, intuition, divergent thinking, sensitivity toward other people, acceptance of risks, learns to move around in the diversity, accept, new roles, among others. The work in Advance Calculus with technology has created a new relationship between the teachers of basic and applied technologies and research groups, which promotes the interaction, aimed at achieving the multidisciplinarity in the process of teaching, the application of new technologies, the transfer to the classroom of research for the best treatment of various subjects; and work in conjunction with the purpose of improving the quality of teaching, and thus to achieve the curriculum objectives. Besides this form of work is closer to the way students will face in their professional life

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REFERENCES


