STRUCTURAL ANALYSIS OF AN AUTOMOTIVE INTERIOR SYSTEM. PRACTICAL LEARNING IN THE CONTEXT OF THE NEW EHEA

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ABSTRACT:

At the IQS School of Engineering, projects has been implemented that bring students to the industrial environment through real cases. This action is in accordance with the philosophy of the European Higher Education Area (EHEA), with a strong orientation towards practical learning rather than classical education tools based on master classes.
In this article, authors want to show their experience from the Area of Strength of Materials and Structures for the Bachelor's Degree in Industrial Technologies Engineering, and specifically to the subject of Mechanics of Materials. To search the preliminary information and to learn about some of the most relevant structural analysis with the Finite Element Method (FEM), such as modal analysis of vibration and elasto-plastic nonlinear analysis, and to use the Center Console assembly from a real car, make this a good active learning experience of mechanical engineering.

Keywords: European Higher Education Area (EHEA), Central Console, Automotive Interior Systems, Structural Analysis, Elasto-plastic Analysis, Noise Vibration Harshness (NVH), Project Based Learning (PBL)

1. INTRODUCTION

Since the European Higher Education Area Universities have been modifying their study programs to increase the coherence and European integration [1][2] giving mobility to students and competitiveness inside the EU. These changes work in the line to solve worries shown during decades by industry concerning universities and research centers: learning impractical. The engineer's education is a key aspect to raise competitiveness, especially in times of (economical) crisis, and university should keep working in maintaining the engineering level (which has been noticeable in Spain, over the years) but emphasizing the practical nature of learning for greater transfer of knowledge to promote innovation [3].

In this way, from the Area of Strength of Materials and Structures of the IQS School of Engineering, sessions that gather the most important part of a real structural calculation exercise in the design of a project-oriented learning and project-based (Project Oriented, POL / Project Based Learning, PBL) have been planned. As multiple studies attest, advantages of this approach surpass the disadvantages encountered in this implementation [4]–[19].

These sessions take place in the course Mechanics of Materials, third-year Bachelor of Engineering in Industrial Technologies, being this a common subject. The course provides students with basic knowledge of the detailed study of the stress and strain fields in elastic solids achieving a wide and complete comprehension of Elastic General Problem, for its later solving using different techniques. In this single case, the used technique is the finite element method MEF. The elastic-plastic analysis can go beyond the elastic environment, as it is currently the case in tests on components inside the static rigidity, where a small remnant deformation value is accepted after removing the applied load. Students are expected to acquire the certification of skills presented in this degree, observing as well the so-called transversal skills.

It is important to be aware of the importance of exercises that most closely resemble the actual execution of engineering, and in this particular case, the practice of compressing the structural design of a set Central Console of a car. Students are meant to use frequency and natural vibrations modes as well as the materials elastoplastic curve taught theoretically in several subjects to understand, evaluate and improve the global rigidity of a product or structure. This rigidity calculation development is part of SEAT-IQS Laboratory, opened in 2007.

The planning of this learning is structured in 4 phases, following the report as learning modality (Project Oriented, POL/Project-Based Learning, PBL) summarized in EA2005-0118 PROJECT [20]: Information, planning, realization and evaluation. These 4 steps have been joint into two working modules: Module 1 (Information and Planning), Module 2 (Realization and Evaluation)

An out of production vehicle has been selected, to keep the maximum confidentiality that an industrial real project like this always required. All those real actions that took place for structural integrity reasons in each of the pieces that make up the assembly discussed and excuse for further learning within the given time.

In most of the situations, an engineering project covers a wide range of interrelated problems that the engineer must solve effectively. Engineering education should include this level of complexity [21]. A system component of the inside of automobile was used. It is limited enough (in terms of number of functional parts) but complex enough (in terms of testing requirements and its relation to the environment inside the automobile). It is considered adequate, for the technological difficulty that offers without the slower understanding related with the assembly process.

The use of the analysis carried out, modal frequency analysis and own modes of vibration (hereinafter Modal Analysis), and nonlinear elastic-plastic analysis (hereinafter Nonlinear Analysis), is important in product development. These simulations rule the evolution of different solutions leading to the final design, optimal to overcome the load cases required to the assembly that is being developed. Together with the explicit analysis, these two types of calculations are essential for proper structural evolution. They can be considered among the most important in CAE analysis. The *Grup d'Enginyeria de Productes Industrials* seeks to promote the comprehension of these type of analyzes for the main role they play in the so-called concurrent engineering.

Some members of this research group have extensive experience in the automotive sector within departments of simulation, having led a long list of calculation projects for many automobile constructor firms. This background is considered important from the proposal viewpoint, being a fundamental component in terms of motivation, while helping to locate perfectly this calculation function with the several interrelated areas in the complete development of the Central Console.

The main purpose of these sessions is the comprehension of the structural behavior of the selected assembly, learning from these two types of analysis, using the ANSYS software. Thus, a real environment of a competitive department of simulation CAE approaches to the university. This work tool has been chosen as one of the most important among the high performance numeric codes of the market. However, intensive or profound training of this tool is not intended, only acquiring the necessary and sufficient knowledge for the proper monitoring of the structural design philosophy behind this learning is.

2. METHODOLOGY. TEACHING EXPERIENCE

The teaching methodology purposed is based on a real exercise of project based learning. Although these sessions are carried out by pairs of students, and in a group (10 students) when the proposed solutions and the results are called into question (Module 2), the development of these also infer directly on individual and personal competences because many of the actions are performed individually. Thus it is achieved, through group cooperation, greater creativity in providing solutions, while individual work empower the responsibility.

The hour distribution has been made by keeping in mind the need to have a basic knowledge for this type of calculation before the monitoring of Center Console can be developed, so that two working modules have been established. A sufficiently large period of 20 hours time has been established to overcome the difficulties while avoiding the penalizing of high workload.

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The organizational modalities to carry out this process of teaching-learning are set in four attendance stages (Theoretical sessions, Seminars, Practices and Tutorials), plus two other non-attendance (Workgroups and Autonomous Labour) [20].

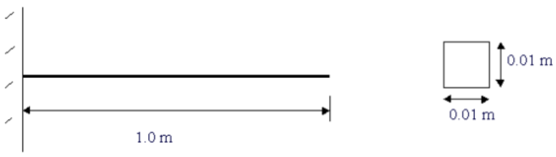
2.1. MODULE 1. RESEARCH STAGE

Step 1: a theoretical presentation marks the start (whole group, 5 couples) like analysis of the scenario or project status to solve (the beginning of the exploring cycle as part of contextualization). The need to achieve a significant degree of rigidity is shown in the Central Console sets to meet the needs of the users. Thus, a feeling of a stable product over the time is achieved (low mechanical wear) and robust in front of static and dynamic charges (static and impact strength), indications of quality for this type of development. Validation of control parameters are presented to ensure that stiffness (arrow, accompanied by equivalent Von Mises stresses). As a group, the main objective of learning through this methodology is identified: to achieve an adequate level of safety for the student to perform CAE analysis. Likewise there is a pooling of the two objectives of the project within the course: use the modal and nonlinear calculation like tools for the product development and learning the bars modeling strategy within a modal analysis to further convergence towards an effective rational solution (improved rigidity in the design of components in the production process). Awareness of a basic level using ANSYS, and the theoretical lesson of modes analysis and vibration frequencies of a simple mechanical model presented in a subject are taken.

Step 2: later, a cooperative work in a small and autonomous group is engaged (by couples). This is an info gathering and self-learning. A Modal Analysis and Nonlinear Analysis study is developed, by each couple. Each student investigates one of these analyzes. This self-learning plan is established by the couple. The following guide questions are formulated: What calculation learning will be relevant? When is this type of calculation used in industry? Which strategies are used to increase stiffness by CAE? The search for these calculations range from the classic book (mechanics, materials strength, …) to the technical article published in indexed journal, through which all information where ANSYS analyzes are made and usually presented in the Workbooks of the same software (any of them available on the Internet) . For this module, it is very important to understand the type of analysis, generically, as individual ANSYS commands. This stage has an important role to ensure the success of the student good monitoring when making the second module. This preliminary study involves a significant degree of self-training by the team (pair of the students) through the search, management and understanding of the information found.

The resources deployed for this first module correspond to a working classroom with internet next to each student's laptop (computer given to each student when he begins the studies in the IQS School of Engineering). The student version of ANSYS, installed on each PC, is also used, restricted in the number of nodes in the model, but full in terms of computing suite. Furthermore, students have the option of consulting the expert in the subject (Mentoring) like a personalized relationship for the optimization of learning, while being aware that the exercise should be done with the greatest autonomy possible by the couple.

One of the strategies applied to advance in the self-study is the execution of simple exercises that can be addressed in two ways of working, getting to correlate the results obtained. A correct correlation does not guarantee 100% good practice in two ways, but poor correlation indicates that something is not being done properly. The strategy and design of these exercises are carried out by the pair of students, and are usually related with beams subjected to axial forces, bending simple or torsion, as well as conditioned unloaded beams for the extraction of modes and vibration frequencies.



	Teórico	M. Subespacios	M. Block Lanczos	M. Reducido
Modo 1	8,35517	8,355	8,355	8,355
Modo 2	52,36093	52,354	52,354	52,356
Modo 3	146,61212	146,570	146,570	146,580
Modo 4	287,30125	287,130	287,130	287,350
Modo 5	474,92955	474,490	474,490	474,580

Fig. 1. Extract example of a delivered report, Modal Analysis. Cantilever beam. Correlation frequency in Hz

In the figure above one of the exercises presented by a couple of students for Modal Analysis is shown. The structure studied is a cantilever beam ANSYS modeled with beam elements type. Correlation established of the analytical value obtained by equation versus simulation, according to the root extraction method used in each calculation, is presented.

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The students proceed to share (Small group, couple) what is individually learned, their information sources and the problems encountered in the search.

Step 3: an introductory monograph on the Center Console from the teacher, around two hours (Master Class), ends this first module. This presentation shows the exploded study domain (Figure 2), the interaction with their environment in vehicle mounted, materials and manufacturing processes, the description of the product specifications and charges notebook (experimental tests) as well as the discussion of some limits on development conditions. It is intended to enable students to have a wider and global view of project implementation even when focused on structural resolution of the set.

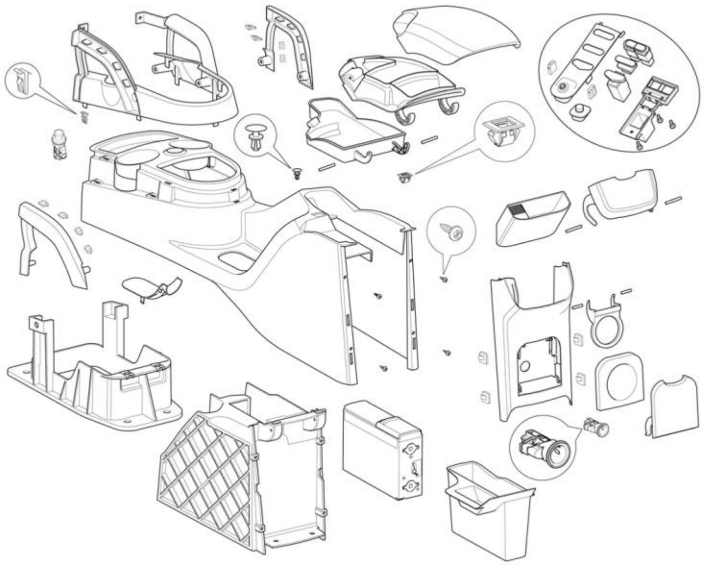

Fig. 2. Set exploded Central Console

In this preliminary presentation the actual planning of a thorough analysis is displayed and discussed to be carried out and what impact would each of them have in the course of development. Then, the extent of the two cases chosen for learning test, represent a smart selection for locating the demanded structural requirements is delimited. Project structural calculation planning to be carried out is established.

2.2. MODULE 2. CENTRAL CONSOLE MODEL STAGE

The second module (Realization and Evaluation) is structured by understanding different processes as (differentiating the actions through) simulation, to be run in the *Laboratori d'Enginyeria de Productes Industrials* (LEPI), and those made in the physical laboratory (*Laboratori SEAT-IQS*).

2.2.1. CAE model. Modal and Nonlinear Analysis

Regarding the virtual laboratory, the activity begins in the Central Console meshing and assembly mode, considering the real interaction between parts of the assembly. The mesh model was created and assembled by the principal investigator of this article, together with a professor of the Area of Strength of Materials and Structures of the IQS School of Engineer, a former member of the department of CAE Faurecia Interior System, Abrera platform. Delivering the mesh directly to the student rather than its creation directly addresses two issues: runtime optimization, and similarity searches with a real project.

Currently, big product development companies, with high technological content, outsources the creation of meshing models to engineers located in low cost countries. As long as large work volumes are held, this practice is economically productive. High quality model are received due to quality mesh control patterns from vehicle manufacturers are strictly

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followed. In the case of Faurecia, like other multinationals, this step is performed in engineering companies located in India. In this case, in the same company Faurecia in Pune platform where response is given to almost the entire volume of mesh that is required daily for all platforms worldwide. Only meshing and refinement tasks are entrusted locally because these tasks imply lesser workload and immediacy.

By the other hand, the mesh modeling with shell-type elements requires some ability, and would need to spend many hours of training for a proper execution. From the tasks that shape a complete analysis by FEM, the pre-process is the least valuable, so that if any dispense is needed it can be and usually is subcontracted (or in this case ignored). However, in order to view the full exercise, a statement of the main problems to be overcome when creating mesh is done (Theoretical session in the laboratory). An execution procedure of the mesh execution from the import of different pieces received in CAD software is explained. Also the strategy implemented for modelling joints (clips, plastic welding, riveting hammers,), accepting usual simplifications typical of a global scale model.

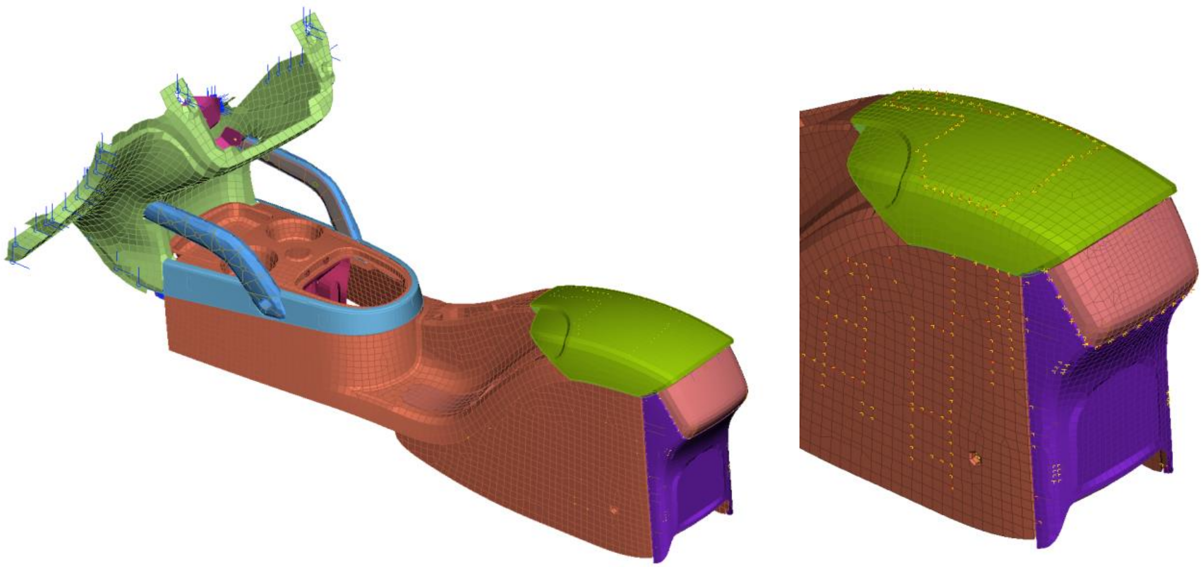

Fig. 3. FEM model of the whole Central Console. Details of some of the union elements between parts

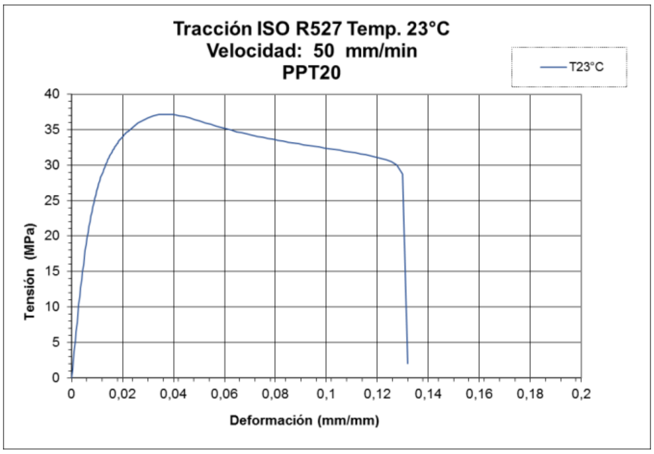

Fig. 4. Elastoplastic curve of the PPT20 tensile material test

Step 4: the first revision of entities is performed from the model received, as is usually done in real project. For this practical scenario, students work individually, having two workstations per couple with the installed version of ANSYS university, which allows working with large models (number of elements), the laboratory is occupied by a group of 5 couples. Sessions show the student how to act (practical classes) with the possibility of consulting the other member of the couple. The materials, the element types and the properties assigned to the elements are reviewed and modeled (element section properties Beam type, thickness in the case Shell type). The modeling of link conditions are presented and discussed with the total group (seminar).

For Nonlinear Analysis, spot stiffness testing has been chosen among the many trials that must overcome the Central Console, as one of the most critical for this component. Because of the lateral tread in the upper area of the set
In the post-processing stage, for Modal calculation, it is performed:

- Obtaining the list of the own frequencies. Validation of these compared to the reference target of 40 Hz (Autonomous Work).
- Display of the own modes of vibration. Interpreting the resistant behavior (Autonomous Work).
- Proposing improvements to increase overall rigidity. First refusal tests of possible actions to be implemented by Beam elements (for further processing to construction details) in order to increase the value of some of the frequencies, especially the first (small group, couple). Later sharing with the whole group and discuss optimal solutions (Seminar).

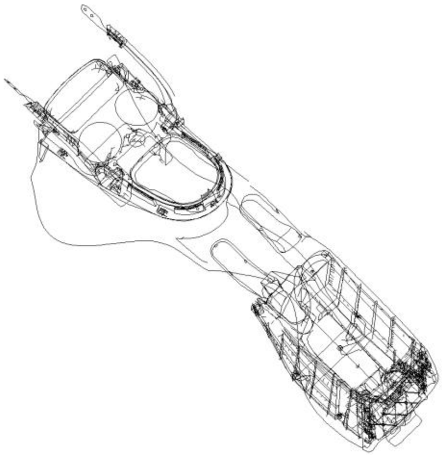

Fig. 5. Own vibration mode corresponding to the fifth frequency

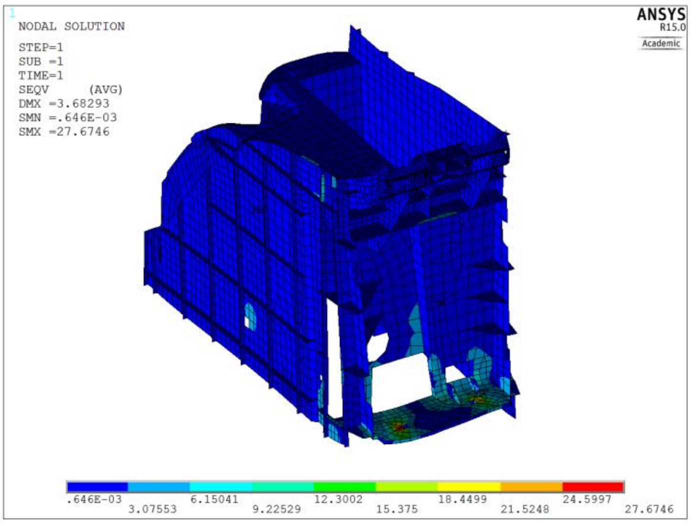

Fig. 6. Map of equivalent stresses of Von Mises, internal Frame piece

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2.2.2. Physical test. Punctual stiffness test of lateral tread

Step 5: the physical testing is performed with the assembly mounted on a tool, respecting the mounting attachment points on the vehicle.

A "stepper" coupled to a dynamometer is used for the implementation and control of the force. The displacement is recorded by a laser meter (HBM Spider8), connected to a computer which will record data over time (small group, couple). The couple records and studies the binding sites to establish a comparison with the FEM model fixings.

Three assays per point are made, for a more precise reading, (use the average as the final value). Three points of action are enabled, being the values of incremental load from 50N to 250N, for each point. The maximum load value corresponds to a situation of non-linearity due to large displacements, but without entering in plasticity, to perform retesting. The importance of recording the coordinates of the hold-down and reading application for correlation with the virtual laboratory is highlighted (Nonlinear simulation, item 1).

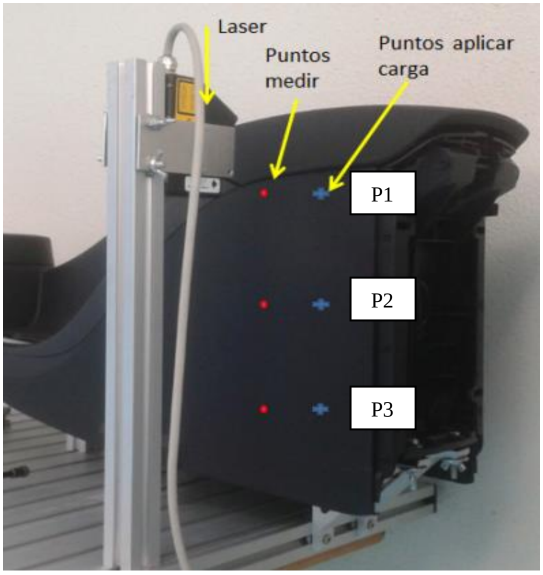

Fig.7. Central Console set on test mechanism. Detail of load points and measurement

2.2.2. Results presentation. Correlation

Step 6: The pairs of students present, as oral presentation, the results obtained in each of the laboratories. An exercise in correlation to the data obtained for point 1 (P1) is performed. Learning development (total group) it's also discussed.

2.2.3. Evaluation

Professor conducts the assessment, individually, taking into account all the steps done throughout the project. The strategy developed in the search of information phase, the documentation and information sources are rated (module 1). For the module 2, the solutions found to improve rigidity (which are those that would be implemented in real project) and the development of the physical test are assessed. The final score is closed with the presentation and discussion, against professors, about those solutions that are considered viable and the learning method.

3. DISCUSSION. CONCLUSIONS

The scores obtained by evaluating skills related to these sessions, over these three years of life of the subject, are high. So, as professors, we are satisfied with the implementation of this project-based learning. The motivation that students show when the engineering approach addresses sets that are familiar and

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attractive, such as those related to the automotive world should be added. The transfer of the teaching of the analysis initially prepared (courses prior to the implementation of this methodology) as theoretical classes to these sessions made by PBL is considered very satisfactory.

Tasks such as literature search (active learning), using a real and good contextualized model and oral presentations are considered very appropriate within the new framework of the EEES. The stage of self-education is very effective to achieve the main objective of this learning methodology: there is a huge confidence gaining in the implementation of CAE analysis, for an autonomic response when similar situations take place in their professional lives. A real problem understanding and knowledge applied for its resolution (acquired in the first module and other disciplines) is acquired, which is the basic purpose of the project-oriented learning. Opportunities to be creative in proposing solutions are provided, especially in the phase that starts form the implementation of beem elements on the CAE model. Dynamically structural trends are very effectively found (shared by seminary). It is true that this type of scenario leads to developments and conclusions based on the reflection, exchange and discussion degree shown by students (involvement), but the discovery and the theoretical and practical contrast are emphasized. It's also achieved some responsibility, albeit limited, in the government of the models. It has managed, in general, that part of the teacher role becoming a facilitator of the learning process. The utility of the PBL teaching strategy is concluded: students acquire skills in structural design, problem solving, information research and intelligent question making, engineering thinking, laboratory techniques and interrelation of under study product parts with each other and the elements outside the realm of work. We believe that PBL is a very good complement to the theoretical and practical classes.

As an aspect of improvement is proposed not to condition the search for information, opening it to any type of CAE analysis (the tutor initially drives the search towards modal and nonlinear analysis). This point would improve the self-learning stage, but it would delay in time. It would also be interesting to implement a shared evaluation (self-evaluation, evaluation of the mate in the couple and the tutor's evaluation, established in several stages), to obtain a more objective result of learning of each student.

Finally, an augmentation of the number of hours that students dedicate to the project is proposed. This would achieve better use of post-processing stage, one of the most creative parts of this project. Note that all learning tending to a more practical side entails more hours of teacher's dedication, especially if they want to squeeze the experience as much as possible. Regarding the student's voice, the 20-hour approach are presented generally pleasant, even short, and show the feeling of having understood many details that relate different disciplines in a practical way (intrinsic motivation, active learning). The initial effort required to search independently is rewarded for results and understanding in laboratories.

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