# Learning of Electrical Machines through Collaborative Multidisciplinary Works.

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***Abstract***- Electrical machines are complex and fundamental equipment in our current life. In the conventional courses of electrical machines its operation is treated from the electrical point of view, however the reality is much more complex. To introduce this to the students of the electrical specialty of the engineering degree in industrial technologies, they are proposed to carry out an academic work on the different parts of a specific electrical machine, of which enough information is available. In this activity, the class is splitted in about 10 teams. Each one of them have to address a topic that is not normally studied or is not studied in great depth in the course. To accomplish the academic work, the students have to find additional information, use actual machine documentation or use standards. At the end, a report must be prepared, and a presentation made for the rest of the class. All the students have worked on a specific machine, but in different facets of it. Each presentation ends with questions among the students of the different teams. Every year the type of machine is changed. The students obtain good marks on this work, which is used as part of continuous assessment.

***Keywords:Electrical Machines, Self-learning, Collaborative learning, Livelong learning.***

## 1. INTRODUCTION

Engineering curricula are supervised by national agencies such as ANECA (National Agency for Quality Assessment and Accreditation) or international agencies, such as ABET (Accreditation Board for Engineering & Technology) or EUR-ACE © ENAEE (European Network for Accreditation of Engineering Education) that verify that the students acquire the necessary competences.

Within these competences we highlight some that have been incorporated last and were not in the old curricula, such as:

- Oral communication.

- Collaboration

- Lifelong learning

Within educational innovation, numerous techniques have been developed that help students to acquire these skills. Within the long list, we highlight some of them as:

-Flipped classroom (Sánchez-Canales et al., 2019)

-Cooperative learning (Centrado, 2011)

-Self learning (Blázquez & Platero, 2019)

-Inquiry-based learning (Sein et al., 2014)

-Challenge-based learning (Manrique & Sanmartín, 2019)

- Collaborative Multidisciplinary Works (Navarro Soria et al., 2015) (Reverte et al., 2007)

In this paper, the experience of multidisciplinary collaborative works is presented, which would be integrated into the last of the previously exposed techniques.

This activity consists of group works where each of these deals with one aspect of an electrical machine. These are aspects of the machines that are not covered in a conventional electric machine course. So, all the students in the class work on different aspects of the same machine. Finally, they must make a presentation of the assigned topic to the rest of the students. There is a round of questions at the end of each presentation by the students and the teachers.

The structure and philosophy of these multidisciplinary collaborative works presented in this paper, can be applied to other technical subjects. Subjects where industrial equipment or systems are studied. This activity aims to serve as a bridge between theory and industrial reality.

The rest of the paper is organized as follows. Section 2 presents the context of the activity, in which grade it is located, its students and its objectives. Later in Section 3, the proposed activity is described. Section 4 details the evaluation method used, as well as the results obtained. And finally, Section 5 summarizes the most important contributions of the paper.

## 2. CONTEXT

Electrical machines are key parts of the electrical power systems, and they are of great importance, not only in electrical systems but also in transportation or in any branch of industry.

Within the Degree in Industrial Engineering Technologies (GITI), the study of electrical machines is divided into several subjects, the first one called "Electrical Machines", is located in the 2nd year of GITI. This is a core subject for all students at the school. Transformers and induction machines are studied, which are the most used machines in the industry. This subject

has a large number of students and only a part of the students shows great interest in it.

The second subject related to electrical machines, is only for students of the electrical engineering track and is located in the 3rd year of the Engineering Degree in Industrial Technologies. It is called "Electrical Machines II". Transformers and asynchronous machines, previously studied, are studied more in details. In addition, other machines, as synchronous machines, direct current machines, permanent magnet machines, reluctance machines and brushless DC machines are studied.

The number of students in the electrical engineering track is small, between 30 and 40 depending on the academic year. They are students with great interest in the subjects of the track, among which is the subject Electrical Machines II.

For this reason, the collaborative multidisciplinary works are proposed to these students.

### *A. Objetives*

There are several objectives in these works such as:

- Study feature of electrical machines not included in a classic university course.

Normally in a classical electrical machines course, the operation of the machines from the electrical point of view is studied. These works are intended to make students aware that electrical machines, and in general any industrial equipment, are more complex and have more features than those studied in the course.

- Researching information.

To carry out this work, students must seek additional information to that provided by the teachers. To do this, they should use the internet and the university's digital library, where manuals, equipment catalogs and standards can be found.

- Work with real documentation of electrical machines.

Students are provided with real documentation of electrical machines such as technical specifications, instructions manual, construction drawings, test protocols, etc. It is usually the first time that students have to use this type of documentation, which has certain differences with the academic documentation used so far.

- Standards.

In some proposed topics, students have to consult manufacturing and testing standards of electrical machines. It is also the first time they have used standards. We believe that it is important to know and use the standards, since it will be a common practice in their future professional life. In this case, they can be consulted in the digital library of the university.

- Teamwork.

Students are divided into groups, between three and five components so they must work as a team. They must distribute the assigned tasks and collaborate for the realization of the report and the preparation of the presentation.

- Public presentation.

At the end of the course, a session will be dedicated to the presentation of the work to the rest of the students. Each of the group members have five minutes to present their part of the work.

- Encourage participation in question rounds

After each presentation, a round of questions is established, generally opened by the teachers, focusing on the most representative aspects of the work. Two targets are important. Firstly, that any member of a team can respond to the questions, regardless of whether the student was in charge of presenting that specific aspect. Secondly, that the rest of the students participate actively by asking their colleagues. We think that it is very enriching that the students are public of the presentations of the other teams, as it is the same machine that they have done the work but related to a different feature.

## 3. DESCRIPTION

The work will be performed on an electrical machine that will be assigned to the class. The type of machine will be changed every year among Transformer, Asynchronous Machine or Synchronous Machine. So that every three years the type of machine is repeated, according to Table 1.

**Table 1** *Electrical Machine types.*

| | |
|---|---|
| **Year 1** | **Transformers** |
| **Year 2** | Asynchronous Machines |
| **Year 3** | Synchronous Machines |

The class is divided into teams of three, four or five students each. In total there will be around ten teams. This depends on the number of students in that particular year. So that the maximum number of works can be assigned with the fewest possible students.

The teachers have all the necessary documentation for the machine. This documentation will be delivered to the students according to the assigned topic.

The available documentation is:

-. Specifications

-. Data sheets.

-. Test protocols.

-. Construction drawing.

-. Instruction's manuals

-. Operation and maintenance manual

-. Electric schemes

-. Instrument List

-. Protection system documentation

-. Manufacturing pictures

All the teams will carry out work on that specific machine, for which they will have access to the available documentation.

The assignments works are related to topics that are not studied or not studied in depth in a classic course on electrical machines. These topics depend on the machine type, but there

are several common topics and specific topics, as shown in Table 2. Figure 1 shows the specific topics for transformers.

Before carrying out the works, each team holds a meeting with the professors to explain the objectives, as well as to briefly explain the theory or at least a brief introduction on the assigned topic, so that the students can work on this topic.

Additionally, a work script is delivered with the general and specific objectives of the work.

The general objectives are related to the study of the assigned subject in general for any machine. The specific part must be adapted to the assigned machine. For example, in the case of machine tests, the tests not explained in class should be described. The general part tries to describe how these tests are carried out. In the specific part, it is about analyzing the tests of the assigned machine protocol. In this section, emphasis is placed on losses, as well as their influence on operating costs.

**Table 2** *Collaborative work topics.*

| | |
|---|---|
| **Common Topics** | |
| **01** | Installation |
| **02** | Constructive forms |
| **03** | Cooling system |
| **04** | Instrumentation |
| **05** | Protection systems |
| **06** | Maintenance |
| **07** | Factory Tests |
| **Transformers Specific Topics** | |
| **T1** | Dissolved gas analysis |
| **T2** | Type and applications |
| **T3** | Tap changer |
| **T4** | Insulation |
| **T5** | Purchase data sheets |
| **Asynchronous Machine Specific Topics** | |
| **A1** | Starting methods |
| **A2** | Starting time |
| **A3** | Type of windings |
| **A4** | Variable speed drive |
| **Synchronous Machine Specific Topics** | |
| **S1** | Excitation systems and automatic voltage regulators |
| **S2** | Speed regulator and types of prime movers |
| **S3** | Temperature influence in the machine capacity |

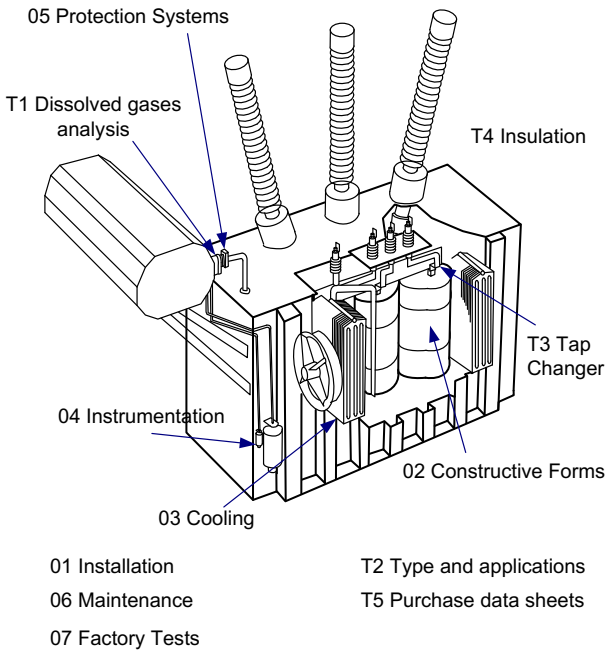


*Figura 1:* Transformers topics.


*Figure 2:* Moodle report and presentation spaces for asynchronous machines.

Afterward, the students begin their work autonomously, dividing the work.

As a final result, they will prepare a report and a presentation of the work carried out. Both will be delivered in electronic format (Fig. 2). Finally, the presentations will be made in the classroom with all the students of the different groups.

## 4. Results

Two rubrics are used to evaluate the competences that the students acquire with the completion of the assignments, one for the presentation and the other for the report.

| Criteria for evaluating the work | | | | |
|---|---|---|---|---|
| | Quality level | | | |
| Criterion | Very Good (3 points) | Good (2 points) | Medium (1 point) | Bad (0 points) |
| REPORT | | | | |
| Report Contents | Search diverse bibliography | Class content only | Some content is missing | The content is not enough |
| Graphics Presentation | All the graphics used help to understand the explanation. There is none that is over, nor is there any missing | At some point in the document, a graphic is missing to help clarify a concept | The way you use the graphics does not help to clarify the concepts. | Does not use graphics |
| Report Clarity | The contents are very clear and the sentences are understood the first time. | Sometimes the sentences are long and confusing, and you have to read them several times to understand them. | The text has many grammatical errors | The text is difficult to understand. The sentences are long and confusing. |

*Figure 3:* Rubric for the evaluation of the report.

As it can be seen in Figure 3, the qualification criteria do not refer to aspects of the student's individual work as a single report is delivered for each group. Thus, in this section the group members obtain a rating between 0 and 9 points.

Regarding the qualification of the presentation, presented in figure 4, the first two criteria (6 points) are related to formal aspects of the presentation. Moreover, the third one (3 points) is related to the performance of each speaker.

Finally, the score is completed with 2 points, assigned by the teacher's, depending on the student's participation in the question turns after the presentation of the rest of the topics by their classmates.

| Criteria for evaluating the work | | | | |
|---|---|---|---|---|
| | Quality level | | | |
| Criterion | Very Good (3 points) | Good (2 points) | Medium (1 point) | Bad (0 points) |
| PRESENTATION | | | | |
| Presentation | The presentation contains a selection of the most important content and is perfectly adjusted to the time available | In the presentation, some fundamental content is missing, but it adjusts perfectly to the time available | In the presentation, some fundamental content is missing and also does not adjust to the time available | The contents presented are not enough |
| Presentation quality | The way of use the resources makes the presentation enjoyable. The size and colors of the text and graphics facilitate correct visualization. | The size and colors of the text and graphics facilitate a correct visualization, but at some point the presentation becomes heavy. | You have to make a great effort to follow the presentation, because it is not very entertaining and because the sizes and colors used are not the most appropriate. | It is impossible to follow the presentation |
| Expression quality | The speaker expresses himself easily, fluently explains the contents of the presentation and correctly answers the questions posed | The speaker expresses himself easily, but does not explain the contents of the presentation fluently enough or does not respond accurately | The speaker expresses himself with difficulty, but seems to dominate the contents of the presentation | The speaker expresses himself with difficulty, lacks fluency in explaining the contents of the presentation and does not respond accurately |

*Figure 4:* Rubric for the evaluation of the presentation.

Thus, from the 20 points that can be obtained with this activity, 15 are common to all team members and 5 are individual performance of each of the students. We consider it appropriate that 75% of the score is common, since it is a teamwork activity.

As an example, Figure 5 shows the distribution of students' grades in academic year 2020/2021.

In Figure 5, each group of bars represents a group (From G1 to G10) and each bar the total score of each student. It is observed that not all the students of the groups obtain the same score. This is due to the individual qualifications criteria applied in the second rubric.

There are also slight differences between the grades obtained in successive academic years. Figure 6 shows the evolution of the average scores of the common part and the individual part of the works.

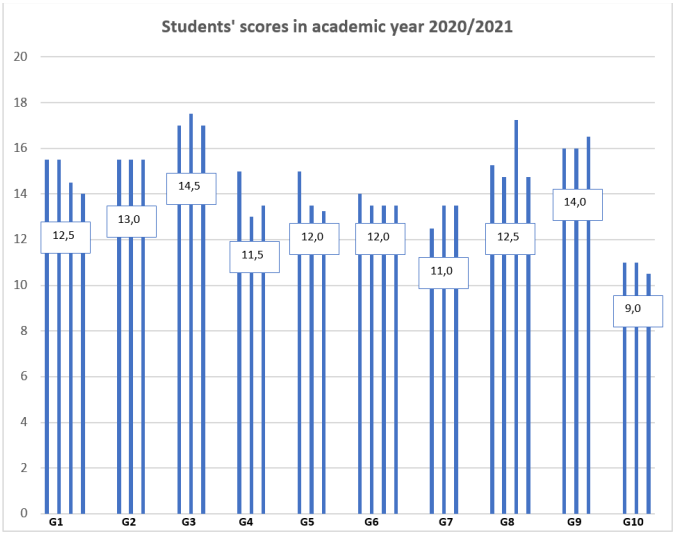


*Figure 5:* Students' scores in academic year 2020/2021. Group 1 to 10.

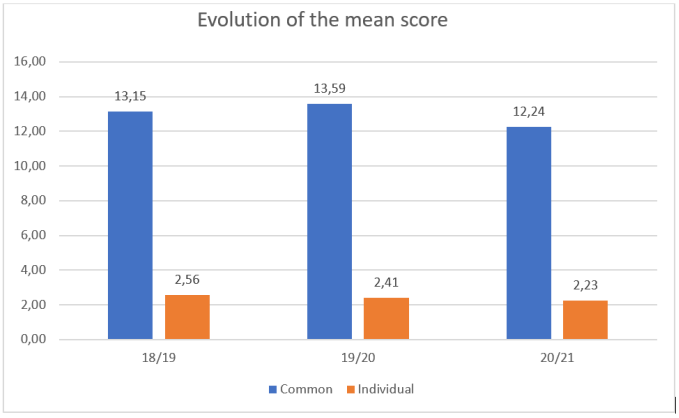


*Figure 6:* Evolution of the mean score for three different academic years.

It is observed that the average scores are high. Although in the last year they have fallen, especially the common part to all the students in each group. Possibly it is due to the fact that this academic year, due to the sanitary restrictions for COVID 19.

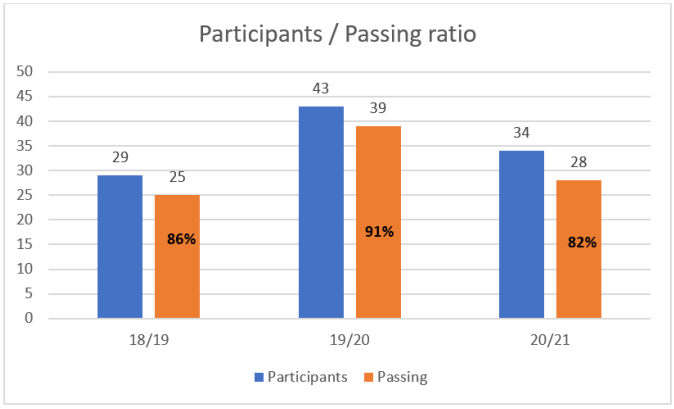


*Figure 7:* Collaborative woks participants and passing students in first call June.

The students have only had 25% of face-to-face classes and also have had limited the possibility of face-to-face meetings, which they have used video conference. In any case, it will be necessary to see the evolution in future courses to be able to confirm these conclusions.

Finally, Figure 7 shows the relationship between the number of students who participate in this collaborative works and those who pass the course at first call (ordinary June call).

It is observed that a large number of students who participate in the collaborative works manage to pass the subject on their first attempt. The percentage of those who passed it is always above 82%, reaching 90% in the last academic year.

## 5. Conclusions

After the analysis of the results, we can conclude that satisfactory outcomes are obtained with the proposed multidisciplinary collaborative works.

Firstly, students study aspects of electric machines unknown to them, with a teamwork methodology, which encourages skills such as initiative, task distribution, autonomous work and public communication.

Regarding learning, it should be noted that the different groups acquire basic knowledge about the subject assigned and some general ideas about the rest of the subjects, presented by the rest of the teams.

The use of rubrics in the evaluation process is capable of discriminating the best works and the best students.

The results obtained in terms of quality, and therefore the scores, are very good over the last academic years.

Finally, it has been shown that the accomplishment of the work has a positive effect on the success on the subject. Moreover, the students' interest in electrical machines increase remarkably.

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