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► To cite this version:

Manuel Melon, Bruno Gazengel. Teaching electroacoustics in a master's degree at Le Mans University : a public-private partnership. 26th ICSV, Jul 2019, Montréal, Canada. <hal-02410575>

HAL Id: hal-02410575

<https://hal.science/hal-02410575v1>

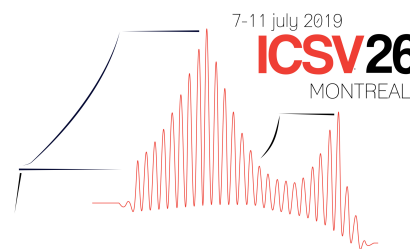
Submitted on 12 Dec 2024

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TEACHING ELECTROACOUSTICS IN A MASTER'S DEGREE AT LE MANS UNIVERSITY: A PUBLIC-PRIVATE PARTNERSHIP

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Le Mans University (France) is a public university (around 11 000 students) specialized in acoustics research and teaching. It offers students Bachelor's and master's programmes in acoustics and more specifically a master's programme in electroacoustics, the International Master's Degree in Electroacoustics (IMDEA). The specialized courses offered in this programme enable students to know how to design, model and measure audio systems (loudspeakers, microphones, ...) in order to work in Research and Development departments in industry in private or public organizations. This programme is also supported by a foundation and the courses are given in English in collaboration with a private engineering school. In this paper, we present the birth of the IMDEA, the admission process for candidates, the organization of the courses, the collaboration with external teachers (from universities or specialized companies). The presentation will focus on student's projects and will show how they enable students to synthesize and strengthen knowledge gathered during the lectures and to create networking with companies. Several examples of projects done by first year and second year students will be given (portable speakers, directive subwoofer, headphones, ...). Monitoring of the project progress and assessment of student's work will be described. Finally, the work done by the student's association (IMDEA Network) in order to enhance the connection with industry and in order to acquire skills in audio systems listening will also be explained. Statistics about alumni will then be presented and discussed.

Keywords: Education, Master's Degree, Electroacoustics, Public-private partnership

Introduction

At the European level, there are not particularly many MSc programmes teaching acoustics, and even fewer entirely dedicated to electroacoustics. Among these degrees, DTU (Denmark), RWTH Aachen (Germany), TU Graz (Austria), University of Salford (UK) have a large part of the curriculum dedicated to electroacoustics or audio. However, no entire programme is fully dedicated to careers in audio transducer design. This article reports on the experience of creating a Master's Degree in electroacoustics based on a public-private partnership. This type of program is quite rare in France, especially for science and technology domain. The first Section describes the creation of the master's degree while the second Part focuses on the recruitment process. The content of the programme is presented in Section 3, a focus on projects is then proposed in Section 4. Information on internships and then on hires after the master's degree is given in Sections 6 and 7 before concluding.

This article complements a conference paper written in French [1] describing the birth of this master's degree by adding the latest developments and professional opportunities for graduates.

1. Birth of the IMDEA Programme

The electroacoustic sector is composed of a very large number of small and medium-sized companies and a smaller number of large groups. It covers a wide range of activities such as consumer electronics, hifi, pro audio, transport, health, etc. However, few audio product engineering programmes exist compared to the large number of sound engineering programmes, especially at the master level. In order to overcome this problem, the EMV foundation, hosted by the *Institut de France*,¹ has decided to partner with Le Mans University² to create a master's degree in electroacoustics: the International Master's Degree in Electroacoustics (IMDEA)³. The foundation's requests were as follows:

- All courses had to be taught in English
- The costs were to be shared equally between the foundation and the university
- International professionals and academics should also participate in the programme
- Student recruitment and graduate hiring should be done internationally

Moreover, the programme must also comply with French education law (in particular the enrolment fees set nationally by decree for all masters programmes). The creation of the curriculum started in 2011, the first students arrived in September 2012 after the national accreditation was obtained.

In France and at that time, this type of programme was rather rare for various reasons:

- For accredited programmes, teaching should be done in French. This law was slightly relaxed in 2013 (Article L121-3 of the Education Code) after the launch of IMDEA.
- The master's partners come from three different types of organisations: a public university (Le Mans University), a private school (ESEO⁴ for electronics courses), a foundation (EMV Foundation). To our knowledge, this type of partnership is very rare in France for a master's degree.

2. Admission Process

In order to recruit students who are both highly motivated and very well-trained in science, a three-step admission procedure has been developed after three years without using any formalized selection process:

1. First of all, an online scientific test is proposed. It lasts a maximum of three hours and includes about sixty questions on audio, mathematics, mechanics, electronics and signal processing.
2. If more than 50% of the correct answers were obtained on the scientific test, the candidate completes an online questionnaire allowing him/her to express his/her motivation regarding audio and electroacoustics. Responses are evaluated by two teachers with a score out of 100.
3. The last step is a file to be completed including the academic (Bachelor's degree grades) and professional background if applicable as well as letters of recommendation. The quality of the file is also assessed with a score out of 100.

Candidates are then ranked according to the average of the scores obtained in the three tests. A maximum of 16 students per year is selected. This selection procedure has been put in place to avoid recruitment errors. Indeed, since candidates come from a very large number of countries and therefore from bachelor programs that we do not necessarily know, it is difficult to make the selection on the basis of academic results only. The first test therefore allows to test all candidates with the same question bank (the test duration also provides information on motivation).

¹<http://www.institut-de-france.fr/institutions/prix-fondations/fondations/fondation-emv>

²<http://www.univ-lemans.fr>

³<http://imdeacoustics.univ-lemans.fr/>

⁴<https://eseo.fr>

Table 1: Course list for semester 1

| Discipline | Course | Credits |
|---------------------------------|----------------------------|---------|
| Acoustics & Mechanics | Acoustics I | 6 |
| | Room acoustics | 2 |
| Communication | English | 2 |
| Electroacoustics | Loudspeaker system | 4 |
| | Microphone basics lines | 1 |
| | Transducer basics | 2 |
| Methods | Instrumentation basics | 1 |
| | Maths for acoustics I | 3 |
| | Matlab for audio | 2 |
| Professional | Seminars | 0 |
| Refresher courses | Acoustic Project Refresh | 5 |
| | Acoustics refresh | |
| | Mathematics refresh | |
| | Matlab Project Refresh | |
| | Signal analysis refresh | |
| | Vibration refresh | |
| Signal Processing & Electronics | Digital electronics basics | 1 |
| | Electronics basics | 1 |

3. Organisation of the courses

The IMDEA Master's programme is spread over 4 semesters. The first three include more than 300 hours of classes, supervised assignments or practical work. The last semester is devoted to a long internship (5-6 months) in a company. As students come from different undergraduate specialities, from different countries, they do not have the same knowledge base. Thus, some have never learned acoustics or electronics. The first month is then dedicated to a refresher cycle including mathematics, acoustics, a practical project in acoustics, signal processing, vibrations and an introduction to programming. After the refresher lectures, the specialized courses of the program begin. The course lists are given in Tables 1 to 3 for the first 3 semesters. It should be noted that some courses are shared with the Master of Acoustics (for a total of about 14 + 24 attending students). A general overview of the repartition by disciplines is also shown in Figure 1.

4. Projects

In addition to the classic format courses, the pedagogical team also introduced project-based learning in order to promote professional situations. There are numerous of project-based learning [2, 3, 4]

- building knowledge and skills through trial and error and in real-life situations, which promotes their acquisition over the long term;
- collective decision-making through exchange with peers;
- development of autonomy;
- student engagement in the task;
- maturation of a professional project;

Two different project sessions are proposed, the first one is scheduled in the second semester of the first

Table 2: Course list for semester 2

| Discipline | Course | Credits |
|-----------------------|-------------------------------|---------|
| Acoustics & Mechanics | Acoustics II | 4 |
| | Continuous systems vibrations | 2 |
| | Vibrations experiments | 2 |
| Communication | English | 2 |
| | Project Management | 1 |
| | Scientific expression | 1 |
| | Tools for job searching | 1 |
| Electroacoustics | Loudspeaker technology | 1 |
| | Transmission lines | 2 |
| Professional | CAD modelling | 2 |
| | Project | 4 |
| Signal Processing | Digital filtering | 2 |
| | LP analog electronics | 3 |
| | Signal analysis I | 3 |

Table 3: Course list for semester 3

| Discipline | Course | Credits |
|-----------------------|-----------------------------|---------|
| Acoustics & Mechanics | 3D sound | 2 |
| | Numerical Vibroacoustics | 3 |
| Communication | English | 1 |
| Electroacoustics | Electrodynamic motors | 2 |
| | Loudspeaker modelling | 2 |
| | Microphone modelling | 1 |
| | Mini and micro transducers | 1 |
| | Radiation of transducers | 3.5 |
| | Transducers measurements | 2 |
| Professional | Advanced Transducer Project | 6 |
| Signal Processing | Adaptive filtering | 2 |
| | Power electronics | 2 |
| | Signal analysis II | 2.5 |

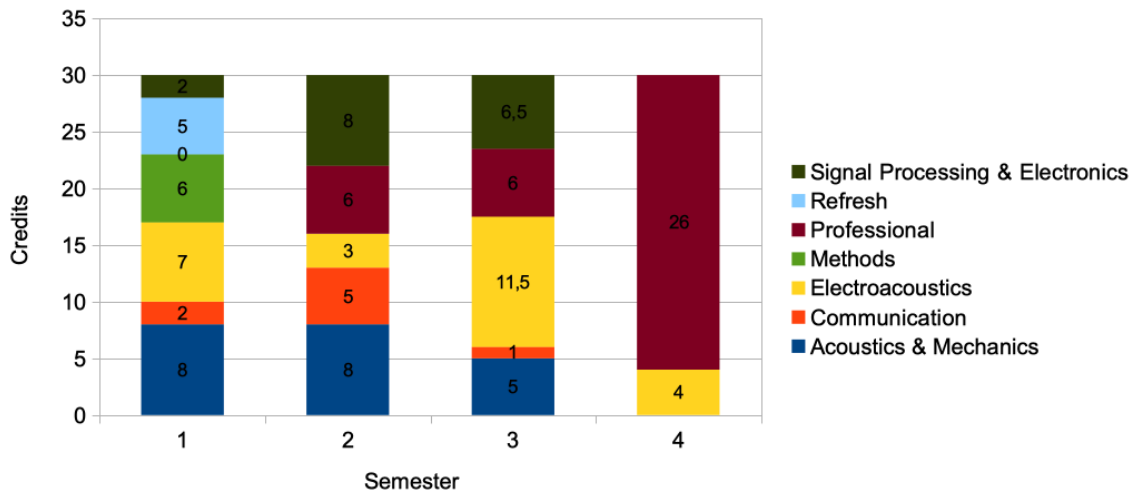


Figure 1: Course repartition

year while the second one is scheduled during the first semester of the second year.

4.1 1st year project

The first year project with a duration of 6 weeks spread over the 2nd semester was first developed in the form of a competition in which students divided into groups of two had to build the same electroacoustic system. Thus, a two-way PVC speaker system [5], a subwoofer with switchable directivity or a portable speaker system have been built according to the different years. Students have a budget of about €150 to buy all the necessary components (retail price). This amount is constraining enough to push students to take up certain challenges (especially the speakers available at this price are not top-of-the-range models). This kind of project requires a large number of scientific and technical skills. This strong transversality is highlighted by the following list: programming mathematical equations on numerical calculation software (Matlab or Python), measuring the parameters characterizing a loudspeaker, predicting the theoretical frequency response of a loudspeaker, designing and manufacturing a crossover filter, measuring an electroacoustic system, becoming familiar with the software used by electroacoustic companies, Using a CAD software, building a prototype, writing and managing a schedule, communicating scientific results in writing and speaking, etc.

This type of project worked well, but having the same subject for everyone was a bit daunting. The pedagogical team then proposed a new formula to solve this problem: the IMDEA Show. Here, the subjects are all different, they can either be proposed by the professors or by the students themselves. In order to strengthen student involvement, the following decisions have been taken: the projects are presented outside the university in the Le Mans start-up incubator. This helps to take students out of their comfort zone and bring them closer to the world of work. The morning is dedicated to oral support while the afternoon takes the form of a professional trade show. Students present their prototype to professionals in the audio world who also participate in the notation. Partner companies such as B&W speakers, Focal JMLab or Orosound support the IMDEA show by participating in the jury and offering gifts to the best groups.

In conclusion, this project met a large part of teachers' expectations. It allowed students to

- to consolidate the knowledge acquired during the year
- to manage a complete electroacoustic project (from concept to prototype);

- to discover some of the limits of the scientific approach in a real problem that affects humans
- to connect knowledge
- to work in a group
- to disseminate their work in writing and orally

Throughout the project, we were able to observe a high level of motivation among all the students. The project supervisors also observed a significant progression of students, both in the understanding and mastery of theoretical concepts and in the use of digital engineering tools.



Figure 2: 2018 IMDEA show: electrostatic speaker (left), a simplified Leslie speaker (middle) and a DML speaker (right).

4.2 2nd year project

The first year project is product-oriented while the second year project is more research and development oriented. Topics are proposed by teachers or partner companies, and possibly but more rarely by the students themselves. Here the numerical or analytical models developed or the signal processing used are more advanced. The proposed six-week period is often greatly increased by the use of personal slots by students demonstrating their degree of involvement. Among the topics covered were: loudspeaker Characterization by the Radiation Modes method, optimization of the subwoofer placement in a listening room, differential circular microphone array, characterisation of a active trumpet mute, etc.

4.3 Dissemination of project results

Whenever possible, dissemination of the project results is performed. For instance, participation in the student design competition of the AES is financially supported by our university.⁵ Students are also encouraged to present their results at AES conventions⁶ or at the French Acoustics Congress (CFA).⁷

5. Internships

During the last semester, students complete a company internship. The IMDEA Master's network is now well provided, so the number of internship proposals is higher than the number of students,

⁵Denys Volkov got a silver medal in 2018 <http://www.aes.org/students/awards/design/aes144.cfm>

⁶<http://www.aes.org/e-lib/browse.cfm?elib=19478>, <http://www.aes.org/e-lib/browse.cfm?elib=20278>, <http://www.aes.org/e-lib/browse.cfm?elib=18602>

⁷https://www.conforfr.fr/cfa2018/output_directory2/data/articles/000420.pdf

allowing them to make a choice on their preferred fields or companies. A map showing the geographical distribution of internships in Europe is provided in Figure 3. The internships are mostly done in the following sectors: hifi, consumer electronic, pro audio, 3D sound or car audio. A significant proportion of students were recruited at the end of the internship by the company where they performed their internship.

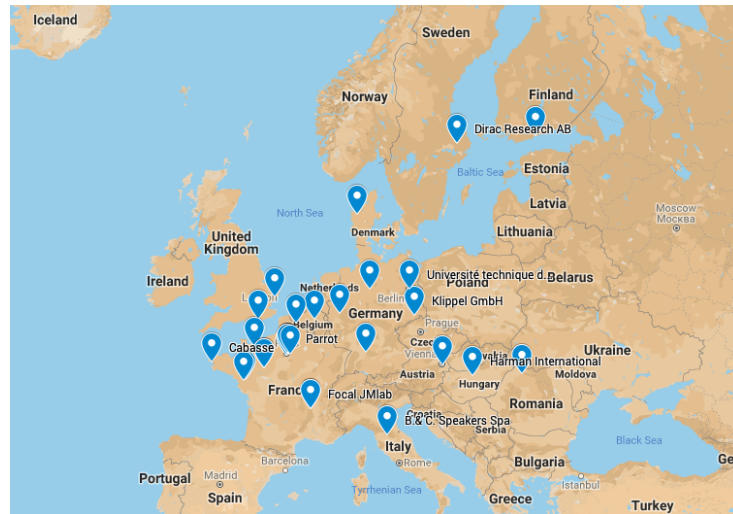


Figure 3: Geographical distribution of internships in Europe. [Click here for on-line version.](#)

6. After the IMDEA

Recruitment after the master's degree is very good. A significant proportion of employers cover internship companies (see Figure 4), thus demonstrating professional satisfaction with the quality of the program. Indeed, 40% of the students were hired in the company where they did their internship. Since 2018, an alumni association (IMDEA Network) has been created to strengthen the links between the different years, thus facilitating internship research and student hiring.

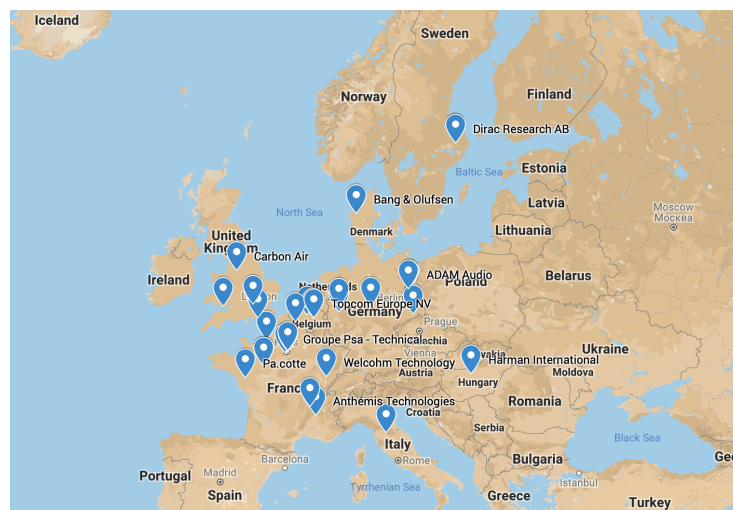


Figure 4: Geographical distribution of jobs in Europe. [Click here for on-line version.](#)

7. Conclusions

For this master's degree, the public-private partnership has provided many advantages. Thus, the additional finances made it possible to improve the administrative functioning (recruitment of an administrative manager in charge of the daily management of the master), to increase the visibility of the master and to improve recruitment (advertising on sites such as Studyportal), to buy quality equipment for practical work and projects, organising visits to companies in the audio field, etc. Teaching completely in English took some time to adapt. However, the efforts made by the teaching team have created a leverage effect for the acoustics laboratory: intensification of internationalization and development of a network at both the teaching and research levels. For example, the number of research contracts in the audio field has increased considerably since the beginning of the programme.

Having partners from industry, a private education structure, a foundation, has required many meetings to set up the Master's degree. However, this openness to other ways of doing things and thinking has increased the level of demands placed on the teaching team, thus improving the programme. Various committees (including representatives of the professional world and alumni) as well as student evaluations questionnaires on the program also allow for permanent monitoring, generating rapid changes and adjustments based on plan-do-check-act (PDCA) cycles.

Finally, this partnership made it possible to create an international master's degree in a well-identified theme: electroacoustics, recruiting talented and motivated students within a solidarity group using a dedicated procedure. One of the weaknesses of the program is the recruitment of female students, which has remained a very small minority since the beginning. To improve this point, a partnership with the company Orosound⁸ has been set up. The latter offers a scholarship of €7k per year for a female student who enrolls in the Master's degree. We hope that this action will soon bear fruit.

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⁸<https://www.orosound.com/women-engineering-scholarship/>