

# Linking analytical chemistry Master's programs: the Franco (Pau)—Spanish (Oviedo) case

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Published online: 22 September 2013  
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## Introduction to Master's programs in analytical chemistry

Analytical measurements are needed for all research disciplines, and are also required by industry and other occupations that need to identify and quantify the different components of a mixture and to know and/or understand how they are distributed in space and time [1]. Analytical chemists are therefore needed by a wide range of industrial sectors: petrochemicals, food, forensic analysis, environment, biomedicine, pharmaceuticals, paper, paint, and many more. No goods (products) can be registered or sold without appropriate certification by use of analytical methods, and analytical chemistry is an important part of the value-added chain of any product [2]. Moreover, approximately 50 % of European Union regulations demand high-quality analytical measurements as proof of compliance [1]. The number of staff in public service with the required experience is now insufficient to fulfill demand [3]; in fact, public service is another field with a high and increasing demand for analytical chemists.

Under the Bologna process, students receive a broad education in chemistry at undergraduate level and concentration on specific areas of study occurs in the more specialized Master's classes. Beyond the basic scientific knowledge and skills, Master's students should meet the requirements of the job market from a long-term perspective. This is the main objective of the Master's courses taught in Oviedo (Spain) and

Pau (France). Fortunately, analytical chemistry departments at both universities are large enough to offer a Master's program in analytical chemistry that fulfills all of the above-mentioned requirements.

## Description of the Master's in Analytical and Bioanalytical Sciences (University of Oviedo)

The Master's program taught at the University of Oviedo covers one academic year and consists of a total of 60 European credit transfer and accumulation system credits (ECTS), divided into two semesters of 30 ECTS each (Fig. 1).

The first semester of the Master's program consists of seven compulsory courses, worth a total of 21 ECTS, covering fundamental aspects of instrumental analysis including standard and advanced chromatography, chemometrics, electroanalytical chemistry, spectroscopy, (bio)sensors, and mass spectrometry. As well as chemistry knowledge and skills, analytical chemists must have expertise in a variety of soft or generic skills (e.g. teamwork, leadership, and good communication). The students acquire competence in such soft skills, together with critical thinking and argumentation, during a compulsory generic course entitled "professional skills in science and technology". Other activities, for example laboratory work in small teams and the writing and defense of the Master's project (i.e. the thesis), also help develop these skills in students. The student workload of the first semester is completed by three elective courses, of three ECTS each, chosen from a specified list (Fig. 1). This last optional component enables students to focus their CV toward specific analytical disciplines, for example clinical analysis, proteomics, food analysis, nanomaterials characterization, environmental analysis, forensic analysis, stable isotope-based methods, and miniaturization.

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**Fig. 1** Universidad de Oviedo,  
Master in Analytical and  
Bioanalytical Sciences

## Universidad de Oviedo Master in Analytical and Bioanalytical Sciences

**Education program: One academic year (60 ECTS)**

### First Semester

#### Compulsory courses (21 ECTS):

- Mass spectrometry for elemental and molecular analysis (3 ECTS)
- Advanced spectroscopic and electrochemical detection methods (3 ECTS)
- Techniques for solid and surface analysis (3 ECTS)
- Sensors and (bio)sensors (3 ECTS)
- Modern techniques in separation sciences (3 ECTS)
- Professional skills in science and technology (3 ECTS)
- Chemometrics and advanced data analysis (3 ECTS)

#### Optional courses (9 ECTS, 3 courses):

- |  |  |   |
|--|--|---|
| 1. Clinical and Pharmacological analysis (3 ECTS)                          | 4. Environmental analysis (3 ECTS)                   | 7. Introduction to Nanomaterials and their characterisation (3 ECTS)                |
| 2. Qualitative and quantitative proteomics and biomarker analysis (3 ECTS) | 5. Forensic Analysis (3 ECTS)                        | 8. Bioconjugation techniques for nano-materials application in bioanalysis (3 ECTS) |
| 3. Toxicological and Nutritional analysis (3 ECTS)                         | 6. Stable Isotope-based methods of analysis (3 ECTS) | 9. Miniaturization and automatization in analysis (3 ECTS)                          |

### Second Semester

#### Compulsory courses (9 ECTS):

- Experimental introduction to advanced analytical techniques in routine and research laboratories (9 ECTS)

#### Professional profile (3+6= 9 ECTS):

- 1. Management of small and medium-sized enterprises (3 ECTS)
- 2. Occupational Risk Prevention: industrial hygiene and risk prevention (3 ECTS)
- 3. Industrial and process analysis (3 ECTS)

#### Research profile (9 ECTS):

- Specialization in advanced analytical techniques in research laboratories (9 ECTS)

#### Stage at a private company (6 ECTS)

#### PROJECT (12 ECTS)

Three of the seven compulsory and four of the nine elective courses of the first semester are taught in English. One of the laboratory groups can also be taught mostly in English, and several instructors are able to supervise the Master's project in English, meaning that up to 85 % of the 60 ECTS of the Master's course can be followed in English. This is very attractive for foreign students.

The second semester includes a compulsory laboratory course of nine ECTS (108 working hours in the laboratory). The main purpose of this laboratory work is to use and become familiar with the instruments and techniques explained during the first semester. Students work in small groups, under the direct supervision of an experienced researcher who provides instruction. High-quality science education requires appropriate resources. Laboratory exercises are the greatest challenge in this regard, because they require access to instruments (which are

usually expensive), dedicated instructors, and a well-selected range of interesting applications. Our Master's program includes access to the instrumentation available at the Scientific-Technical Services (SCTs) [4], which is intended to support research groups at the University of Oviedo and at other public institutions and private companies [5] and consists of a series of laboratories and workshops divided into four sections (chemical measurement, characterization of solids, biomedicine, and technological support), equipped with sophisticated equipment, and operated by highly qualified technical assistants. Because the equipment involved (HPLC or LA-ICP-MS, ESI-QTOF, MALDI, LIBS, X-Ray, FT-IR, HPLC-ESI-QQQ, GC-MS, SDS-PAGE, nanostructured electrochemical sensors) is very expensive and its use requires intensive training, students do not work independently in the laboratory running their own projects (this occurs later, during the Master's project). Instead they

receive short, practical teaching courses (6–14 h) in front of the instruments, delivered by recognized experts. At the end of each course, selected standards and real samples are analyzed by the students under the supervision of the instructor. Students are also responsible for subsequent data analysis, which must be presented as a small report for each separate experiment.

Then, as can be seen in Fig. 1, students can choose between two different study profiles. Those more industry-oriented will follow a three-ECTS course mostly taught by professionals from private companies, and will perform a tutored internship at the laboratory of one of the 20 associate companies. Students more attracted by research and academia will follow a more specialized, laboratory-based, nine-ECTS course.

Finally, all students will perform a 12 ECTS Master's degree project, either within a research group at the Department of Physical and Analytical Chemistry or in one of six associated research institutes and technological centers (ITMA Materials Technology, Carbon National Institute, Regional Institute for Research and Agrofood Development, Regional Institute for Milk Products, Asturias Central University Hospital, and National Institute of Silicosis). The students choose from a list of projects that covers all the topics included in the Master's. The project deals with attractive analytical topics, and consists of a short literature review and of corresponding experimental work in the laboratory. The final assessment includes:

1. writing a scientific report (the thesis);
2. presentation of results; and,
3. discussing results with adjudicators.

As the final part of the Master in Analytical and Bioanalytical Sciences, the Master's project is intended to prepare the student for a career in industry, research academia, or other areas of society.

This Master's course has accepted graduates from different fields, including science (chemistry, physics, biology), health sciences (pharmacy, medicine), and engineering (chemical engineering, food technology), and from different regions of Spain. Professionals from private companies and research institutes have also followed it to update their knowledge of instrumental analysis. It has been reasonably successful in terms of number of students, with an average of almost 19 students each year for the last three academic years.

### Description of the Master in Analytical Sciences for Life and Environment (University of Pau)

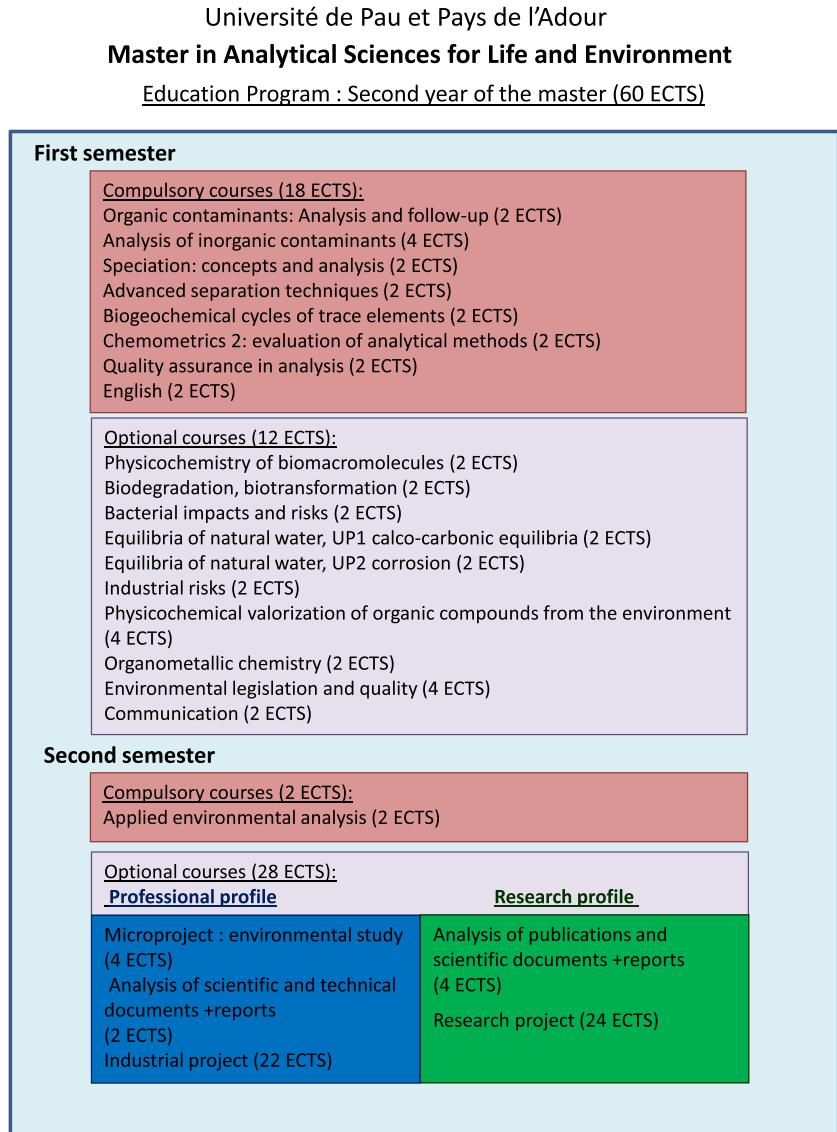
The Analytical Sciences for Life and Environment Master's offers training focused on chemistry, strategies, methods, and analytical techniques applied to environmental issues. The second year of the Master's is the one involved in the double

diploma, and is divided into two semesters of 30 ECTS each. The detailed contents of the Master are given in Fig. 2.

During the first semester students are enrolled in seven compulsory courses, worth a total of 18 ECTS, covering fundamental and instrumental aspects of analytical chemistry including advanced separation techniques, atomic and mass spectrometry, electrochemistry, and sensors. Other important aspects of analytical chemistry, including "chemometrics for evaluation of analytical methods" and "quality assurance for analytical chemistry," are also covered in these compulsory courses. Because the Master is mainly focused on environmental analysis, other courses are devoted to trace element speciation concepts and to biochemical cycles of organic contaminants and trace elements in the environment. As for the Spanish first semester, Master's students are strongly encouraged to develop not only scientific competence but also other skills required for professional success. Depending on whether the purpose of their Master is industry orientation or a research career, students choose 12 optional credits from 24 possibilities covering industrial risks, environmental legislation and quality, communication (CV editing, job interviews), equilibria of natural waters, organometallic chemistry, physicochemical valorization of organic compounds from the environment, and topics oriented toward biological aspects including proteomics, effects and risks of bacteria, and biodegradation and biotransformation of contaminants. In this way students can build up their CV in accordance with their professional focus.

During the second semester the only compulsory course (two ECTS) is a laboratory course in which the students work in small groups of three to four people and use the techniques studied during the first semester under the supervision of an instructor. The objective of this course is to mimic proficiency testing based on analysis of a reference material, for which the different groups have to report data obtained by use of at least three different techniques. For this work, on the basis of their own knowledge and of bibliographic reviews, they have to define their own procedures for sample preparation (depending on the sample matrix, available equipment, etc.) and analysis (technique, concentration range, and quantification method). The procedures must be agreed by the instructor before the analysis is performed. The results submitted by each group are evaluated by the instructor by use of a *z*-score performance test, and each group must then comment on their own results and on the results of other groups. For this purpose the students have access to both the dedicated materials of the training laboratories and to the research equipment of the analytical department of the Laboratory of Analytical Bioinorganic and Environmental Chemistry (LCABIE), which provides sophisticated equipment and is operated by highly qualified technical staff who are fully involved in this course. The financial aspect of such analyses is important knowledge for future professionals: students should therefore include in their report a cost evaluation

**Fig. 2** Université de Pau et des Pays de l'Adour, Master in Analytical Sciences for Life and Environment Education Program: Second year of the master (60 ECTS)



of the different analyses performed, and must comment on the matter after the performance scoring.

After this compulsory course students are divided into two groups, again depending on the focus of the Master, and choose 28 optional credits, as can be seen from Fig. 2.

The industry-oriented group has three weeks' training (four ECTS) in the LCABIE as “research initiation”, during which they are given a small study to perform under the direction of a researcher acting as instructor. As well as the scientific objectives of this work, communication, team working ability and critical thinking are also greatly developed by this training and are evaluated by means of a short oral presentation (10 min) followed by questions on the work performed. The supervisor is also required to fill in a form regarding the student's behavior and attitude (practical skills, involvement in the work and in the research group, punctuality, communication, etc.) A course on

technical documentations (norms, guidelines) and report preparation (two ECTS) is also given. A six-month stay in a private company (22 ECTS) concludes the Master. Evaluation of this training is performed via a written report and an oral presentation, to which the industrial supervisor is invited so they can comment on the work done and on the professional skills of the trainee.

For the students involved in a more academic-research-focused Master, a course on critical evaluation and writing of scientific publications and reports (four ECTS) is included. The students are then given a research subject (24 ECTS) that they must perform over 5–6 months under the supervision of a researcher acting as an instructor. The subject is chosen by the student from a list proposed by the members of the LCABIE and covering all LCABIE's research topics, from proteomics to analytical developments in mass spectrometry or micro-

electrodes. The proposed subjects are part of the supervisors' research programs, and can lead to publication if valuable results are obtained during the research period. A short review of literature on the chosen subject is written, and experimental work is then performed in the laboratory. The assessment of this work includes the writing of a scientific report (the thesis) and an oral defense during which the results are presented and discussed with adjudicators.

This Master's course has accepted graduates from different fields, including chemistry, biochemistry, and chemical and environment engineering. An average intake of 12 to 15 students for the last three academic years, selected on the basis of CV and motivation letter evaluation, enables good supervision for each student, 20 to 50 % of whom (corresponding to the students involved in the academic-research study profile) enroll in a PhD diploma after graduating from the Master. The industry-oriented students usually obtain positions in industry or in private research laboratories. Knowledge of analytical instruments and methods enables graduates to occupy managerial positions in analytical chemistry laboratories and R&D departments in public and private services, and to participate in environmental analysis research and development programs. Graduates from this course take part in the technical activities of design, implementation, control, or expertise related to analytical sciences, both in environmental analysis and in other fields including chemistry, biochemistry, agrochemical, pharmaceutical, and biomedical. This can be seen from the professional occupation inquiries performed by the university for every graduate, at intervals of one year and 30 months after completion of the course.

## Double diploma agreement

The double diploma Master's in Analytical Sciences is the result of long and fruitful collaboration between the Laboratory of Analytical Bioinorganic and Environmental Chemistry (LCABIE; Professor Ryszard Lobinski and Dr Olivier Donard) at the University of Pau and the Analytical Spectrometry Group (Professor Alfredo Sanz-Medel) at the University of Oviedo. The collaboration between the analytical chemistry departments of the universities dates back to approximately 15 years ago, and is demonstrated by the large number of Master, PhD, and post-doctoral students exchanged (8) and by the number of researchers from one university serving on PhD defense and Habilitation tribunals at the other university (12). The two laboratories also meet every two years at an international conference, the Franco-Spanish Workshop on Bioinorganic Analytical Chemistry. This event is a forum for the exchange of ideas between the two groups, and its structure is very different from that of conventional conferences. The objective is to create a warm atmosphere in which PhD and post-doctoral students

assume the lead in all activities, facilitating the exchange of ideas and experience among them.

After an intensive discussion trying to establish the basis of the double diploma agreement, in which the academic authorities were directly involved, and after the visit of the coordinator of the Spanish Master, Dr Jorge Ruiz Encinar, to the University of Pau during summer 2010, the agreement was finally signed during the first semester of 2011. Five students of the Spanish and French 2011–2012 classes were the first to receive their double diploma in September 2012.

A well-organized consortium can be stronger, because it is able to provide better human and material resources [2]. However, such consortia may find it challenging to harmonize their Master's programs. In particular, collaboration and agreements between Spanish and French Master's courses can be complex because the countries' higher education systems structures are different: 3+2 years in France and 4+1 years in Spain. One answer to this problem is a double diploma agreement. In our case, the Université de Pau recognizes the fourth undergraduate year in the University of Oviedo as equivalent to its first year of Master's study. In this way, Master's students can attend the second semester of the fifth year in the partner university and obtain the double diploma. Of course, students accessing the double diploma must fulfill specific requirements, which depend on the country they are coming from. Students accessing the double diploma via the University of Oviedo must have followed the four years of the Spanish B.Sc. program and be enrolled in the Master's in Analytical and Bioanalytical Sciences. Students accessing via the University of Pau must have already taken the three-year French B.Sc., and must have followed the first year of the Master in Analytical Sciences for Life and Environment and be enrolled in its second year. In addition, Spanish and French students must demonstrate the required fluency in French or English and Spanish or English, respectively.

In addition to the obvious advantage of obtaining another international diploma, the students participating in the double diploma are expected to develop a range of essential soft skills at Master's level, including communication, foreign language, leadership, flexibility, adaptation to changing situations, and interaction with persons from other environments and/or disciplines. Such skills are often present in most of the top employability skills lists.

Up to four students from each university can apply for the double diploma. The other students simply follow the entire Master at their own university. Selection criteria are on the basis of curriculum vitae (mostly the student's record) and foreign language knowledge. In the last academic year (2011–12) three Spanish and two French students spent their second semester at the partner university, with very successful results. The defense of the Master's projects of all the exchanged students took place in Oviedo last June 2012, just before the celebration of the seventh International Franco-Spanish

Workshop on Bioinorganic Analytical Chemistry. The adjudicators comprised two instructors from each university. Students were required to make the defense in a language other than their native language. Half of the students presented the Master's project in the language of the partner university, showing that this exchange experience is also multilingual and multicultural for the student (they can apply for almost free French or Spanish courses in each of the partner universities). Experience during the first year of the agreement has showed that the background knowledge of the French and Spanish students was very similar, so they could integrate easily in the exchange Master without the need for any extra tuition. The successful academic results obtained seem to indicate that the double diploma agreement works and is well balanced. Of course, more years of exchange will be necessary to draw more solid conclusions.

In terms of teaching exchange, three instructors teach 10 hours at the partner university. Subjects taught at the University of Oviedo by instructors from Pau mostly cover chemometrics and mass spectrometry, whereas advanced chromatography, nanotechnology, and stable isotope methods are taught by the Oviedo instructors at the University of Pau. This theoretical and practical exchange is very good for the corresponding university partner, as both French and Spanish students have access to a greater number of international experts in different fields.

In the academic year 2012–13, the double diploma has been awarded a grant funded by both the Spanish and the French Ministries of Education and Science, in collaboration. All joint and double degrees between French and Spanish universities can apply for such competitive bilateral support, which covers both teaching and student exchange.

**Acknowledgments** The authors acknowledge the professionalism of all the instructors involved in both Master's programs, and the support of the Governing Bodies of the University of Oviedo and University of Pau. Economic support via mobility grants for students and instructors from the Spanish and French Ministries of Education is also acknowledged.

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Jorge Ruiz Encinar has been an associate professor at the University of Oviedo (Spain) since 2010. His research interests are mass spectrometry and stable isotope-based methods, mostly applied to environment, speciation, and heteroatom-tagged proteomics, and the development of new biological applications of functionalized nanoparticles. In 2007 he was awarded the Young Chemist Prize by the Spanish Royal Society of Chemistry. He is currently the coordinator of the International Master in Analytical and Bioanalytical Sciences at the University of Oviedo.



Brice Bouyssiere has been a professor at the University of Pau since 2013. Before this he performed post-doctoral research with the Group of Trace Element and Element Species Analysis (GKSS, Geesthacht, Germany). His research interests are mass spectrometry methods applied to speciation analysis in petroleum samples and to study of metabolism of platinum anticancer drugs during treatment. Dr Bouyssiere was the Erasmus coordinator at the University of Pau from 2008 to 2012.



Florence Pannier has been a professor at the University of Pau et des Pays de l'Adour (France) since 2008. Her research interests include the development of analytical methods based on coupled techniques, including HPLC or GC coupled with AFS, ICP-MS or MS, for use in speciation analysis of metalloids and, particularly, selenium. In this area, her main research field is determination of unknown species in a variety of matrices of toxicological or eco-toxicological concern. She is currently the head of the Master of Chemistry and coordinator of the International Master in Analytical Sciences for Life and Environment at the University of Pau.