

How the “COLOUR in Science and Industry (COSI)” Master Degree meets academic excellence and industrial needs

Juan Luis Nieves*, Javier Hernández-Andrés, Markku Hauta-Kasari¹, Jon Yngve Hardeberg² and Alain Tremeau³

Optics Department, Faculty of Sciences, University of Granada, Spain

¹School of Computing, University of Eastern Finland, Finland

²Department of Computer Science, Faculty of Information Technology and Electrical Engineering, Norwegian University of Science and Technology, Norway

³Faculty of Sciences and Technologies, University Jean Monnet, France

Email: jnieves@ugr.es*

The aim of this paper is to introduce the good practices and expertise of the Erasmus+ Joint Master Degree “COLOUR in Science and Industry (COSI)” in recruitment of excellent students, teaching, learning and employability. COSI is a 2-year international master programme (120 ECTS) developing interdisciplinary trained experts in sectors encompassing colour, spectral and digital imaging in applied science and in applications development and analysis. The objective of the programme is to educate students in advanced methodologies, applied models and practical applications with two main goals: enhance the employability, and improve career prospects of graduates on one hand and meet the needs of industrials on the other hand.

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Introduction

Erasmus+ Erasmus Mundus Joint Master Degree (EMJD) “COLOUR in Science and Industry (COSI)” is a two-year (120 ECTS) Erasmus+ Joint Master Degree, aiming to train the next generation of highly-skilled industrial experts in applied colour science, in various cutting-edge industries (photonics, optics, spectral imaging, multimedia technologies, computer graphics and vision) in a diverse range of sectors (including multimedia, health care, cosmetic, automotive, food-processing) bridging a talent gap in the industry where colour experts are in high demand. The 2 areas of focus are spectral technologies and applied colour imaging. COSI is brought to students by a world leading university-business cooperation of 4 European universities (University Jean Monnet - UJM, University of Granada - UGR, University of Eastern Finland – UEF, and Norwegian University of Science and Technology - NTNU), 5 Asian universities and 15 industrial leaders across the globe (Figure 1).

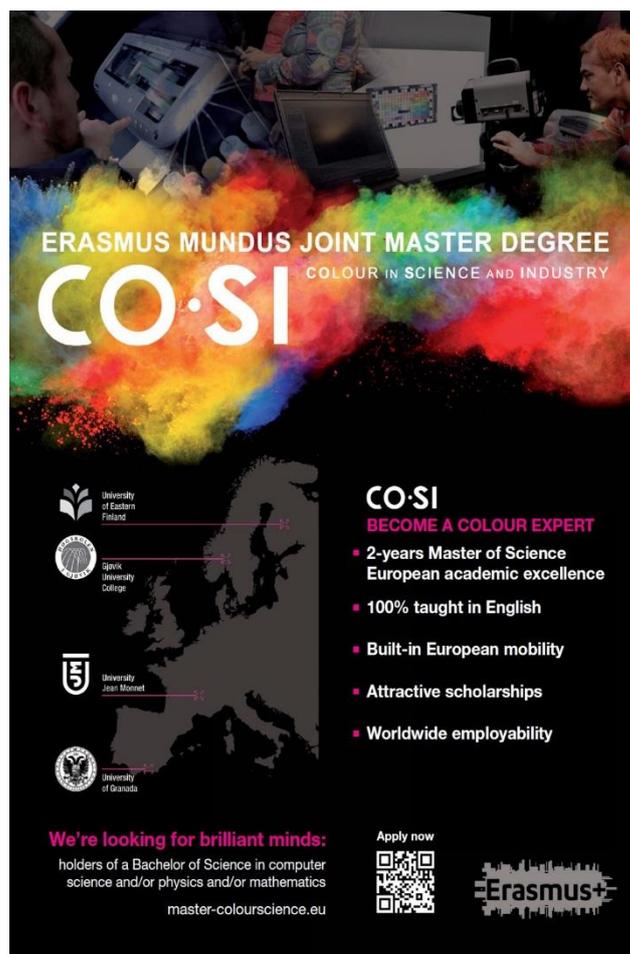


Figure 1: Erasmus+ EMJD Colour in Science and Industry (COSI) logo and flyer where the geographic location of the four consortium partners (Finland, France, Norway, and Spain) is included.

The COSI consortium has progressively built an expertise in: - designing joint master/doctoral programmes of excellence; - managing students' and staff's mobility; - shaping academic/scientific exchanges, especially between EU and Asia. Since several years COSI has established very fruitful relationships with several Asian HEIs (Higher Education Institutions), such as Chulalongkorn University in Thailand, Toyohashi University of Technology in Japan, Monash University Malaysia in Malaysia, Jadavpur University in India, to name a few. These HEIs contribute to promote COSI in their campus, country and network of partners. They are also involved in some teaching activities (staff exchanges), supervision activities (such as projects, internships, master thesis), research activities (such as co-supervision of PhD works, research projects), etc. Every year we have some student candidacies from these HEIs, especially from Chulalongkorn University and Jadavpur University. The national/international ranking and the reputation of HEIs from where applicants come from counts only for 10% in the COSI selection criteria, likewise recommendation letters count for 10%. Consequently, the fact that an applicant was graduated from one associate partner HEI counts significantly in the selection process. COSI students contribute sometimes to research projects involving one or several COSI partners (for example EU and Asian partners), as a consequence they have the opportunity to be associate as co-author of some publications. The above-mentioned founding partners have set-up over the past decade tight relationships on colour sciences teaching and research, leading to several multiple degrees and a flagship Erasmus Mundus initiative that have become reference programmes in their respective academic and industrial fields such as:

- The Master in Colour in Informatics and MEdia Technology (CIMET), led by UJM, UGR, UEF and NTNU was funded by the Erasmus Mundus programme from 2008 to 2014 (for five intakes), next was self-funded up to 2017;
- The Erasmus Mundus EACOVIOE (Enhance the Attractiveness of Computer Vision and Robotics in Europe) Programme, from 2009 to 2011, jointly operated by UEF, UGR, ITB and TUT;
- The European Union COST Action COSCH (Colour and Space in Cultural Heritage) led by UEF and NTNU since 2012;
- The Master 3D Multimedia Technology (3DMT), a double master degree operated by UJM and NTNU since 2012;
- The Erasmus Mundus Al-Idrisi a North/South mobility programme for students and academics between UGR and UJM, among others.

All above initiatives are clear examples about how COSI is the answer to the lessons drawn from pioneer courses implementation, its intimacy to industry challenges and the continuing efforts of the founding partners to further unite and increase the attractiveness of the consortium.

Excellence, innovation and competitiveness in terms of academic fields/subjects targeted

A key feature of the COSI program is a focus on advanced and emerging fields in the use of colour and spectral imaging technologies and related data processes. Through this, students will obtain fundamental knowledge and experience of state-of-the-art technologies and methods from leading European institutions, through new high-level R&D-oriented specialist courses with direct application to world of work. This will contribute to increase the quality and the attractiveness of the European Higher Education Area. Specific disciplines include: optical components and systems, measurement and automated vision, medical technology and life sciences, colour science and applied colour imaging, and data science (Figure 2).

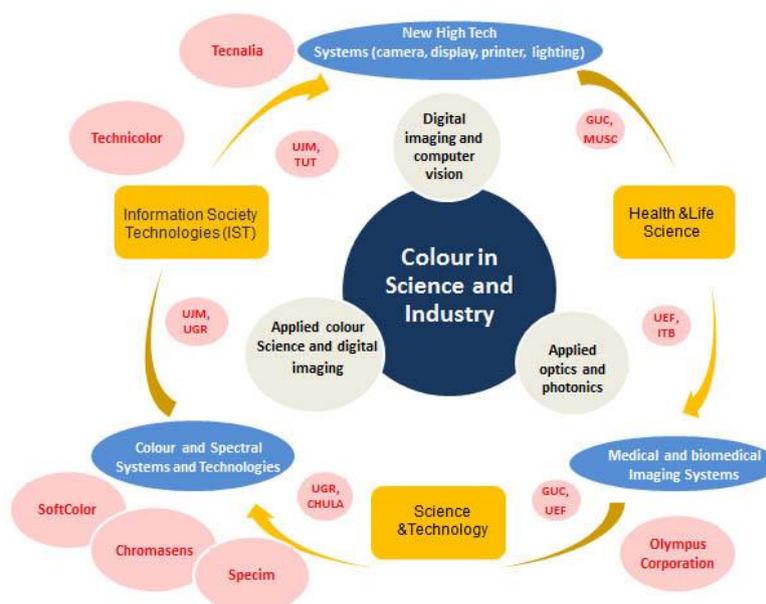


Figure 2: Examples of research fields covered by the COSI programme and complementary between consortium members and companies.

COSI gives students an opportunity to benefit from the complementary expertise and specialisations of 4 leading European institutions and of their Associate Partners, in the field of colour and imaging science. Thus the program is organised around three integrated taught semesters, each offered by a different institution, and a Work Placement in the fourth semester (see Table 1 or online at <https://master-colorscience.eu/course-catalogue/>).

Semester 1 (Sep -Feb)	Semester 2 (Feb - Aug)	Semester 3 (Aug - Jan)	Semester 4 (Jan - Sept)
<p>Fundamentals (UJM) 30 ECTS</p> <p><i>Mandatory courses: 30 ECTS</i></p> <ul style="list-style-type: none"> ▪ Optics and Photonics (5 ECTS) with a focus on: Radiometry, Photometry, Interaction between light and matter. ▪ Color Science and Color Management (5 ECTS) ▪ Digital Image Fundamentals (5 ECTS) ▪ Algorithmic and Programming (5 ECTS - level 1) or Algorithmic and Programming (5 ECTS - level 2) ▪ Scientific Methodology and New Trends in Color Science (5 ECTS) ▪ Data Analysis and Statistics (5 ECTS) <p><i>Optional courses: (Extra ECTS)</i></p> <ul style="list-style-type: none"> ▪ Other scientific course related to ICT, statistics or photonics fields (5 ECTS) ▪ Introduction to Matlab (2 ECTS) ▪ French language and culture (2 ECTS) 	<p>Pre-specialization (UGR) 30 ECTS</p> <p><i>Mandatory courses: 20 ECTS</i></p> <ul style="list-style-type: none"> ▪ Applied Advanced Colorimetry (5 ECTS) ▪ Fundamentals of Spectral Science (5 ECTS) ▪ Advanced Color Image Processing (5 ECTS) ▪ Computer Vision (5 ECTS) <p><i>Optional courses: 10 ECTS</i></p> <ul style="list-style-type: none"> ▪ Image Acquisition and Reproduction (5 ECTS) ▪ Fourier Optics (5 ECTS) ▪ Data science (5 ECTS) ▪ Human Perception and Cognition (5 ECTS) ▪ Spanish language and culture (2 ECTS) 	<p><u>Track 1 (UEF)</u> 30 ECTS</p> <p><i>Mandatory courses: 15 ECTS</i></p> <ul style="list-style-type: none"> ▪ Computational Color (5 ECTS) ▪ Advanced Spectral Imaging (5 ECTS) ▪ Machine Learning (5 ECTS) <p><i>Optional courses: 15 ECTS</i></p> <ul style="list-style-type: none"> ▪ Industrial and Biomedical Imaging (5 ECTS) ▪ Industrial Project (5 ECTS) ▪ Other scientific course related to ICT, statistics or photonics fields (5 ECTS) ▪ Digital Entrepreneurship and Innovation (5 ECTS) ▪ Finnish language and culture (2 ECTS) <p><u>Track 2 (NTNU)</u> 30 ECTS</p> <p><i>Mandatory courses: 22.5 ECTS</i></p> <ul style="list-style-type: none"> ▪ Processing and analysis of visual data (7.5 ECTS) ▪ Computer Graphics Fundamentals and Applications (7.5 ECTS) ▪ Applied Color Imaging (7.5 ECTS) with a focus on Medical, printing, textile, packaging, HDR/capture applications <p><i>Optional courses: 7.5 ECTS</i></p> <ul style="list-style-type: none"> ▪ Machine Learning and Pattern Recognition (7.5 ECTS) ▪ Advanced Color Management (7.5 ECTS) ▪ Selected research topics in color imaging (7.5 ECTS) ▪ Other scientific course related to applied computer science (7.5 ECTS) ▪ Digital Entrepreneurship and Innovation (7.5 ECTS) Norwegian language and culture (7.5 ECTS) 	<p>Master thesis: 30 ECTS</p> <p>In a company or a research center</p> <p><i>Optional courses: (Extra ECTS)</i></p> <ul style="list-style-type: none"> ▪ Scientific courses taught in other international master programs coordinated by TUT, Monash University Malaysia, CHULA ▪ Japanese, Malay, Thai, Indian, Iranian and Italian languages and cultures

Table 1: Course catalogue of the current COSI programme.

Integrated organisational approach and excellence of the consortium accredited by the Education, Audiovisual and Culture Executive Agency (EACEA)

How does our EMJMD “COlour in Science and Industry (COSI)” reflect a common and integrated approach by the consortium? This was one of the key questions to address during the COSI development. The COSI project aims to provide a high level of integration in its joint study programme and contribute to excellence and attractiveness of the European higher education system by: - fostering quality improvements, innovation, excellence and internationalisation in HEI; - increasing the quality and the attractiveness of the European Higher Education Area; - improving the level of competences and skills of Master graduates.

All aspects relating to the organisation of the EJMD COSI are discussed and agreed by the Consortium. The consortium is organised in two separate authorities integrating all partners of the consortium. The Academic and Management Board (AMB) and the Quality Assurance Board (QAB) have distinct activities but will interact to ensure a constant evolution of the programme. The aim of the joint management team is to deliver a unique Master programme with the symbiosis of four full partner's input. Thus, that will be achieved through a jointly designed curriculum based on the most efficient and value-added mobility, a single recruitment strategy and implementation, common learning outcomes, and a single and consistent (internal and external) quality review evaluation of the programme.

Beyond the governing bodies, their activities and decision making, the programme is managed in an integrated way through the use of ICT tools. An online project management platform is commonly used by all actors of the project. This platform allows to centralise and manage all aspects of a project such as internal communication, action planning and data & file sharing, etc. For example, the four local coordinators will have permanent access to student's academic results and transcript of record delivered by all partners.

Besides, the EMJD COSI programme operates with several key elements tailored to incorporate jointness: a single online application platform centralising all students' applications and used by all members of staff in France, Spain, Finland and Norway to consult and evaluate applications, a joint evaluation procedure with common admission criteria and policy, centralised and shared academic data (grades file, transcripts) that can then be integrated in the partner institution's student studies systems (from registration to diploma delivery), a single and systematic mechanism that ensures the recognition of ECTS from all participating institution, a joint Master thesis policy and guidelines (from implementation to evaluation, including a joint event for the thesis defence days), and integrated mechanisms allowing the delivery of three Master degrees accompanied by a joint diploma supplement, from the coordinating institution, describing in details the studies, specialisation and performance of the student. For the consortium and the partner HEIs, our objective is to attract the best students and invited speakers/professors in Europe and beyond and contribute to raising the attractiveness of our universities at Master level and thus of the European Higher Education Area. We aim to prepare and implement an integrated programme with our four institutions and our Associated Partners (mostly European companies) in order to generate a permanent dialogue, analysis and reflection on the needs of the target employment sectors, the competence to develop, the skills to acquire, and the best ways to operate and evaluate the programme. This will contribute to foster quality improvements in our HEIs and lead to excellence. The design of COSI provides learning mobility in higher education in up to four different EEA countries and over a two-year programme, including work placement. This integrated study mobility will ensure a high percentage of employability of post-graduates.

In addition, it is remarkable the added value of the learning and internship mobility for the students (Figure 3). Students are studying and interacting in diverse environments and cultures in Spain, France, Norway and Finland. They are developing intercultural awareness, languages learning skills and adaptability to multicultural environment (from daily life to the world of work) and acquiring solid transversal competences (e.g. working remotely with a team) that will be extremely useful for our post grads' employability and their efficiency and flexibility in enterprises.



Figure 3: Students interacting in diverse environments and cultures in Spain: visiting the Alhambra monument (Granada, Spain), and introducing study placement.

Another key feature of the COSI program is its selection process. While the majority of applicants has only a BSc (in computer science, physics or engineering) every year we also select some applicants having a MSc or a professional experience. Consequently, most of the COSI students are between 24 and 26 years old, although some are older. As example Sean Cooper who was selected in 2015 (at 22 years old) had a BSc in Motion Picture Science. He also had a strong professional experience as production assistant in a post-production company in USA. Alireza Alizadeh Razin who was also selected in 2015 (at 34 years old) had a Bachelor of Polymer Engineering-colour technology and Science and a strong professional experience as colour and paint inspector in an Iranian engineering company. Lingcong Zhao who was selected in 2016 (at 29 years old) had a BSc in chemical engineering and technology and a strong professional experience as assistant manager for displays inspection at Samsung. Last example, Yat Hong Lam who was selected in 2016 (at 28 years old) had a MSc in physics and a solid professional experience in the semi-conductor domain as engineer. All these examples demonstrate that the professional experience and the expertise developed by applicants during their studies are important features taken into account by the COSI selection committee. This counts for 20% in the COSI selection criteria. Motivation and interest for the program is also another very important feature which also counts for 20%. GPA, ranking and distinctions are also essential but can be compensated by the two other criteria discussed above.

The number of women in science master studies is generally lower than that of men. Nevertheless, in COSI every year we have lot of women applications, for example 30% in 2017. In COSI there is no gender discrimination from application to enrolment (e.g. 61% of COSI students selected in 2017 were women). In 2015, we recruited only 15 students, 3 of them were European (Netherlands, Spain and France), all others came from the rest of the world (India, Iran, Russia, Georgia, China, Thailand and Nigeria). In 2016, we recruited 17 students from various countries (e.g. Kazakhstan, Turkey, Brazil, Guatemala,

Mexico, New Zealand ...). Lastly, in 2017, we recruited 17 students from 15 different countries. The profiles of COSI students are very different from one year to another one, depending of their background, nationality, professional project, areas of interest, ... Consequently, teaching and learning activities have to be adapted to these profiles. For examples, applicants with low skills in programming or Matlab do not follow the same courses as more experimented students. Likewise, topics of laboratory sessions and projects are every year adapted to the areas of interest of students.

In summary, the key to success is the integration of all resources, talents, areas of expertise and good practices. The consortium, with its joint governing bodies, procedures and mobility aims to create the best conditions to operate a successful joint master degree achieving the EMJMD aims and objectives.

Quality of the project design and implementation

The Quality Assurance Board (QAB) is in charge of the quality process over the period of implementation of COSI and assured the internal quality of all aspects of the COSI programme. It generated questionnaires that were distributed to: students, teaching staff, scholars/guest lecturers, academic advisors, local coordinators, consortium coordinator and administrative administrator, and industrial partners. They also planned and made interviews with students. Through its quality policy, the QAB gave advices and recommendations to the Academic Board and checked annually if these recommendations were effectively implemented to guarantee the academic excellence of this master program.

One lesson we have learned about quality assurance is that such a process is essential for a smooth and transparent management of an international master programme with several institutions. It is very important to: anticipate any individual or unexpected problems and to be able to find very quickly a solution to all problems; and to be very strict with master programme rules and rigorous with the application of these rules.

Another lesson that we learnt in the past with the Erasmus Mundus students, and now with Erasmus+ students is that they are always very demanding, which is positive when they ask to learn/know more about one topic. On the other hand, when students ask for individual exemptions or too much flexibility, there is a risk that other students ask also to generalise, to extend, individual exemptions to all. Therefore a certain flexibility is allowed in COSI, for example depending of their background students can select a lower or a higher level course in programming. Students can register in optional courses, and after few weeks can freely drop out of optional courses if they want, but after more than a few weeks it is not possible anymore. When they apply for COSI, students have to select which specialisation they would like to follow in semester 3. They can change their mind during the first year of the programme up to six months before the third semester. Deadline for reports submission can be delayed if for example too much learning activities or projects are scheduled in the student agenda, but no individual exemption can be tolerated. COSI programme was built from four national official degrees awarded by four European Universities. The quality of this master programme was consequently also assured by the quality assurance procedures of each national quality assurance body upon which the consortium depends, according to a periodicity defined by these procedures. For instance, at UGR, two different quality assurance procedures were connected to the COSI program: the consortium QAB procedures (which applies to all members of the consortium), and a local quality procedure, which applies only to COSI students at UGR. In the latter case we have designed an English version of the quality questionnaires that UGR distribute among all local students. At UEF, UJM and NTNU local quality procedure are also applied.

Questionnaires are generated every semester at the corresponding partner university and are analysed by the QAB. A meeting of the QAB local representative and the students takes place also at the end of every semester. Furthermore, the student representative from each cohort is a permanent member of the QAB and they actively participate in the analysis of the questionnaires results and in the discussions. The minutes of QAB meetings, with clear advices and recommendations, are sent to the Academic and Management Board (AMB) and published at the COSI website.

Besides, the students are closely followed, from an academic and professional point of view, during the programme by the program academic staff of the Consortium partners (Figure 4).

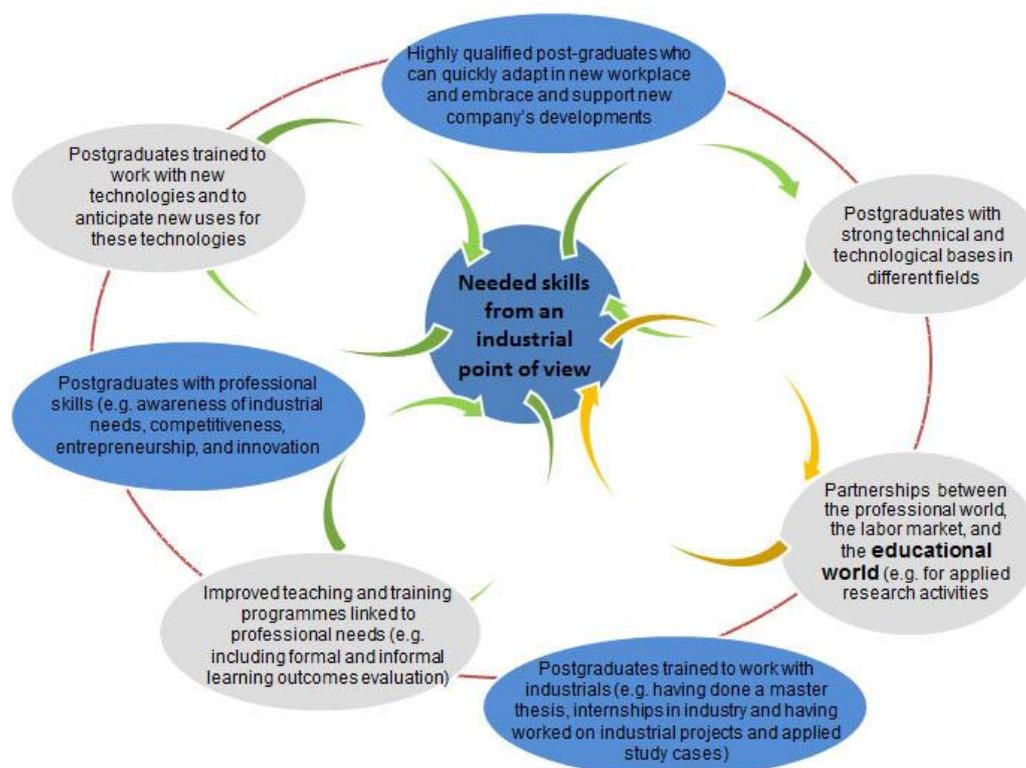


Figure 4: Formal and informal competences and skills covered by the COSI programme and the link with industrial needs.

They are guided in their orientation and advised in their different initiatives. Based on individual competences and interests, the COSI academic staff proposes ideas or helps working out student's ideas and provides guidance using their university contacts and personal networks. Through seminars, students have the opportunity to share and gather useful information for their personal career development. In addition, each partner university provides the student with an academic tutor, a PhD holder or near completion to one. Every semester each student has a new local tutor. Local tutors are in contact and exchange with previous tutor(s) who were assigned to each student in previous semester(s). The students and their tutor meet at least each month to monitor progress toward achievement of learning outcomes. These tutors are, in general, alumni from the previous Erasmus Mundus master CIMET run by the four full partner institutions, who are currently working as teaching staff, PhD students or post-doc at each institution. They are young scientists who studied a master with quite similar characteristics and they have, consequently, a clear perspective of the academic issues that current students could face.

Detailed examination methodologies and performance assessment criteria (ECTS granted, weighting methods, examination duration and nature) are included in each course syllabus prior to the beginning of the course. Grading rules are also included in each course syllabus. All course syllabuses are available and updated every year at COSI website <https://master-colorscience.eu/course-catalogue/>. Each course, despite the partner institution, has two examination sessions. In case of failed course the student can take a resit exam to pass the course. The organisation of the resit exam is the same at each institution. This resit can be done at distance if mobility to another Hosting Institution has already happened. In addition, each institution shares the same graduation rules as established in the Student Agreement (<https://master-colorscience.eu/student-agreement/>).

With regard to plagiarism an information session is given to students during their induction week. No tolerance is allowed in any reports (laboratory session report or master thesis) and in implemented codes. Advices are also given to students on how to write a master thesis or a scientific/technical report, and how to cite any work done by another one. In addition, the COSI teaching staff is strongly encouraged to give, at the beginning of their course module, clarification regarding specific performance assessment methods and expectations. Each full partner must apply national and institutional regulations at the institution responsible for the delivery of the course module in case of fraud and/or plagiarism.

A joint programme for applied research and innovation coupled to industry-to-market services

The objectives of the European Commission actions in research and education are to ensure European leadership in the generic and applied technologies at the heart of the knowledge economy. All actions aim to increase innovation and competitiveness in European education, businesses and industries and to contribute to greater benefits for all European citizens. COSI contributes to these overall objectives by offering joint European curricula in innovative applied research areas that add a significant value to the academic education of students as well as by fostering European prominence in the educational and scientific international arena and industrial related fields.

Thus, another key element of this master program is to prepare students for the global labour market. The master program is designed to address industries' needs and challenges, mainly in the fields of digital imaging and computer vision, photonics and optical technologies, and all colour and spectral technologies (Figure 5). For example, students enrolled in cohort 3 worked on two industrial projects funded by a French company, one the largest seed company in the world. The objective of the first project was to segment image areas of carrots longitudinal sections from colour. The objective of the second project was to detect a ColorChecker Passport in non-controlled (outdoor) lighting conditions. In 2016, students enrolled in cohort 2 worked on another project proposed by a Swedish company, one of the leader company in the world for decor paper products. The objective of this project was to select the best combination of features to improve the relevance of the colour appearance measurements of decor papers and to analyse through data mining methods a dataset of several hundreds of samples produced in the last 10 years. The continued evolution of those research sectors requires adapted and extremely specialised training and qualification. Each year, there is a high demand for postgraduate courses in Electronic Imaging, Colour Instrumentation, Photonic and Optical Technologies and Applied Research in Europe and also in other parts of the world, especially in Asia. Companies that will hire COSI graduates include Technicolor, Nokia, Hewlett Packard Corp., Xerox Corp., Samsung, Orange, and a number of SME's, number which is increasing in emerging technological fields such as Information

Displays or Colour in Medical Imaging and in Biomedical Optics. Therefore, the number of patents in these domains increases each year. Some of these companies have large research units in Europe, and others have participated in COSI to strength and increase collaborations abroad (e.g. Olympus Corporation in Joensuu, Finland area).

COSI students are strongly encouraged to do Summer Internship and Master Thesis work in relation with Industry. Many industrial partners are involved in the master program in various ways: education program (e.g. seminars), visits to their companies, research activity (e.g. project contest), funding of grants (e.g. summer internships, master thesis, PhD grants after completing the master), quality board, expert board, contract positions, etc. Up to now the rate of employability of our students is close to 100% (for students who complete their master with at least a good score). Table II resumes the professional activity of past CIMET and COSI students (data come from a total of 116 students).

Position	%
Postdoc	4.3
PhD student	19.8
Working in a company	32.8
Researcher	12.1
Unemployed	5.2
Other professional activity not in relationship with these master programmes	11.2
Unknown	14.7

Table 2: Current positions of former CIMET and COSI graduates.

Conclusions

This paper discusses different challenges addressed in the development and implementation of the Erasmus+ Joint Master diploma (C) "Colour in Science and Industry (COSI)". After running the previous Erasmus Mundus master "Colour in Informatics and Media Technology (CIMET)" during 9 years, the same consortium implemented a new COSI programme in 2015 to improve the level of competences and skills of COSI master graduates and their employability in the field of colour science and colour imaging. Very few international master programmes benefit from the prestigious and very competitive label EMJMD issued by the Education, Audiovisual and Culture Executive Agency (EACEA) of EU. This label aims "to foster excellence, innovation, and internationalization in HEIs".

The COSI programme combines quality assurance, a strong past experience in innovative tools for teaching and learning, a vast network of associated universities and companies abroad, and an appropriate management process to solve for many difficulties inherent to such kind of international master programme. In the near future, the COSI consortium will apply for a renewal of the EMJMD label to cover recent hot topics in colour and spectral imaging, such as deep learning methods for visual data and data science based methods for video and spectral imaging. Our aim is to adapt the level of competences and skills of COSI master graduates to the evolving needs of the industrial world.

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