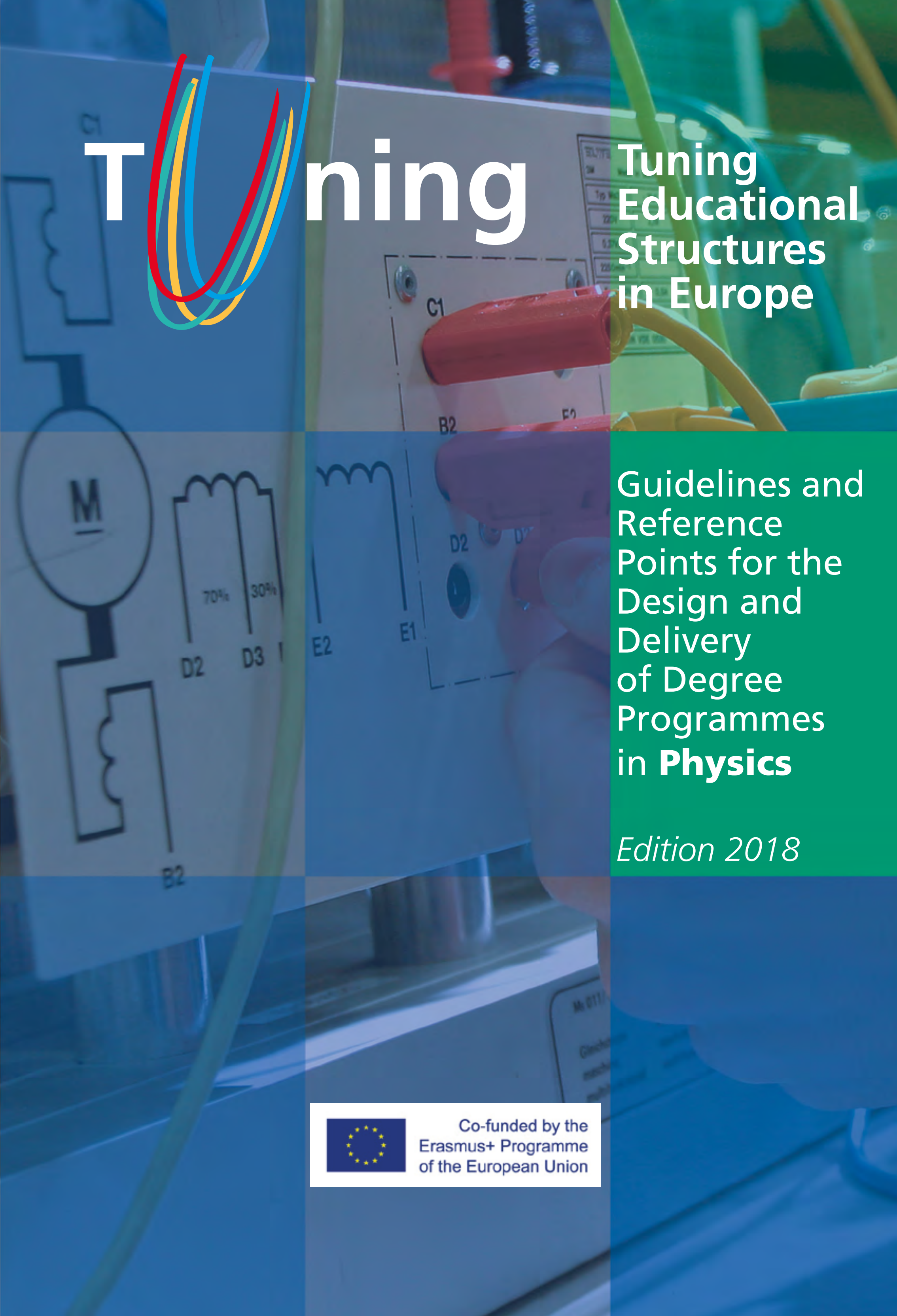
Tuning

Tuning Educational Structures in Europe

Guidelines and Reference Points for the Design and Delivery of Degree Programmes in **Physics**

Edition 2018



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Guidelines and Reference Points for the Design and Delivery of Degree Programmes in

Physics

Edition 2018

Ornella Pantano and Fernando Cornet, eds.

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Groningen

Tuning Educational Structures in Europe

TUNING reflects the idea that universities do not look for uniformity in their degree programmes or any sort of unified, prescriptive or definitive European curricula, but rather for points of reference, convergence and common understanding. The protection of the rich diversity of European education has been paramount in TUNING from the very start and it in no way seeks to restrict the independence of academic and subject specific specialists, or undermine local and national academic authority.

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For more information about the CALOHEE project: calohee@rug.nl

CALOHEE website: https://www.calohee.eu

Tuning – CALOHEE Project Team

University of Groningen:	Robert Wagenaar, project-coordinator
	Ingrid van der Meer, project manager
University of Deusto:	Pablo Beneitone
Educational Testing Service (ETS):	Thomas van Essen
Educational Testing Service (ETS-Global):	Maria Victoria Calabrese

Executive summary

The present edition of the *Guidelines* has been issued in the context of the project 'Measuring and Comparing the Achievement of Learning Outcomes in Higher Education in Europe (CALOHEE)' [1], an EU project aimed to develop the infrastructure for setting-up multi-dimensional tests for each of five subject areas, representing five significant academic domains: Engineering (Civil Engineering), Health Care (Nursing), Humanities (History), Natural Sciences (Physics) and Social Sciences (Education).

In this document the results of the work of the Physics Subject Area Group is presented. This group was composed by 15 members representing different European countries, and a student delegate. The exchange of ideas among different countries and institutions has allowed identifying which competences a student should achieve upon fulfilment of physics degree, and to reflect on good teaching, learning and assessment practices to meet the target. These competences, formulated as learning outcomes, are summarised in the **Tuning Subject Area Qualifications Reference Framework** (Meta-Framework) **for Physics** (presented below as the executive summary) and the much more detailed **Tuning-CALOHEE Assessment Reference Framework for Physics**, which is the main outcome of the project in relation to the Physics Subject Area.

The work of the SAG started by analysing the specificity of the Physics Subject Area and the offer of physics degree courses across Europe (**Chapter 2**). Although details of the programs may vary according to different national perspectives, traditions and educational policies, we found an agreement about what constitutes the core of a physics degree and the profile of physics graduates. Physics is both an experimental and a theoretical subject that requires both analytical and creativity skills. Acquaintance with experimental work and with the use of mathematical and IT tools are therefore an essential part of the profile of a physics graduate. In fact, physics graduates are usually equipped with a rich package of transferable skills, which make them eligible for a great variety of careers even outside the realm of physics.

This analysis was the first step to the development of the Tuning-CALOHEE Assessment Reference Framework for Physics (**Chapter 3**). To identify specific learning outcomes for physics, the SAG also referred to previous Tuning works and other national and international qualifications frameworks. According to the Tuning philosophy, great importance has been given to the development of generic competences alongside subject-specific ones. We ended up with a set of 9 dimensions, that were matched to the dimensions of the QF-EHEA and split into sub-dimensions for further specification. For each sub-dimension, measurable learning outcomes were formulated as descriptors of the EQF categories 'Knowledge', 'Skills' and 'Responsibility and Autonomy'. This scheme was applied to both the bachelor (EQF level 6) and master (EQF level 7) levels to obtain the final Assessment Frameworks.

The process of identifying the dimensions of the Assessment Reference Framework included a reflection on the most appropriate teaching, learning and assessment strategies needed to achieve the desired learning outcomes (**Chapter 4**). Here we describe some 'good practices' for one of the subject-specific dimensions of the Reference Framework (Dimension 3: Experimental design and scientific inquiry), highlighting the connection between the teaching, learning and assessment strategies and the Reference Framework descriptors. We believe that this example could serve as a paradigm for designing learning progressions for all the dimensions of the Reference Framework.

We hope that this publication will be of interest to many, and look forward to receiving comments and suggestions from the stakeholders, in view of further improvement.

The Tuning-CALOHEE Physics Subject Area Group

TUNING Qualifications Reference Framework of General Descriptors in the Subject Area of Physics

Explanation

The Subject Area Qualifications Reference Frameworks (Meta-Profiles) presented here are the outcomes of elaborations by groups of informed academics and students and of consultations of a wide circle of stakeholders. The frameworks have been developed in the setting of the project *Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe*, which is an integral part of the TUNING initiative to modernize higher education.

The Reference Frameworks are based on a merger of the Qualifications Framework of the European Higher Education Area (QF of the EHEA) and the European Qualifications Framework for Lifelong Learning (EQF for LLL). Their integration allows for combining two different philosophies and facilitates the use of the frameworks presented here in different contexts. While the QF of the EHEA covers in particular the learning process, the EQF focusses on the preparation for life in society and the world of work.

The descriptors in the Reference Frameworks are organized on the basis of 'dimensions'. A dimension indicates a constructive key element, which defines a subject area. Each subject area is based on a multiple of dimensions. These dimensions are linked to the five strands of the QF of the EHEA. By applying the categories of the EQF for LLL each dimension involves three descriptors – knowledge, skills and autonomy and responsibility ('wider competences') -, which reflect a progressive level of achievement.

The Subject Area Qualifications Reference Frameworks are meant to serve as a sound basis for defining the *programme learning outcomes* of individual degree programmes of the first and second cycle (BA and MA). Basing the individualized sets of learning outcomes on the frameworks will guarantee that 'standards' which have been agreed and validated internationally are fully respected. It also implies full alignment with the overarching descriptors of the two European Qualifications Frameworks and, consequently, with the National Qualifications Frameworks. Templates in WORD are available on the CALOHEE website:

https://www.calohee.eu

TUNING Qualifications Reference Framework General Descriptors of a Bachelor Programme in the Subject Area of PHYSICS (LEVEL 6)

QF EHEA 1st cycle descriptors	SQF domain dimensions Level 6 (BACHELOR)	EQF descriptor Knowledge Level 6 *Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles*	EQF descriptor Skills Level 6 *Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study*	EQF descriptor Autonomy and Responsibility (Wider Competences) Level 6 *- Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts* *- Take responsibility for managing professional development of individuals and groups*
I. Have demonstrated knowledge and understanding in a field of study that builds upon their general secondary education, and is typically at a level that, whilst supported by advanced textbooks, includes some aspects that will be informed by knowledge of the forefront of their field of study	**1.Theories and models**	Describe the fundamental concepts, laws, models and theories of classical physics and elements of modern physics, as well as their application across a number of real-life situations.	Use physical concepts, laws and theories from various domains of physics to model, analyse and explain simple physical phenomena and problems.	Identify relevant physics theories and models required to interpret phenomena, observations, and real-life situations.
II. Can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study	**2. Mathematical methods**	Name and describe standard mathematical (analytical and numerical) tools and methods and their application in the context of physics theories.	Apply standard mathematical (analytical and numerical) tools and methods to solve problems in physics.	Identify and employ standard mathematical (analytical and numerical) tools and methods to solve problems and model situations.
	3. Experimental design and scientific investigation	Describe standard methods, instrumentation, techniques, theories and regulations used in experimental physics.	Design a simple experimental investigation, using standard instrumentation and follow guidelines, and apply basic methods, techniques and theories for data collection, analysis and reporting.	Set up and carry out simple scientific investigations safely under supervision.
	4. Problem solving	Link physics concepts and laws with basic strategies, procedures, tools and criteria for framing, representing, solving and validating the results of a problem.	Categorise problems based on physical principles, analyse a problem, recognise its structure and devise a (creative) plan for its solution, execute the devised plan and check for its validity.	Address problems from the point of view of physics, identifying the laws and concepts that apply in a specific situation, devise and carry out a (creative) plan for reaching a solution and check its validity.
III. Have the ability to gather and interpret relevant data (usually within their field of study) to inform judgements that include reflection on relevant social, scientific or ethical issues	**5. Scientific culture**	Describe the main traits of the historical and epistemological development of physics and relate them to changes and/or issues in technology, society, and the rules of the scientific community.	Select with guidance and use sources of information on the history and current development of physics and on epistemology, and analyse some relevant examples also in relation to technological and societal issues.	Identify some common ideas and approaches in different areas of science also in relation to its historical and epistemological evolution, and evaluate the influence of science on technology and society in some relevant cases.
	6. Work ethic and integrity	State general ethical principles, norms, values, and standards relevant to the work of a physicist, as well as some examples when physics influences health, environment, politics and/or society.	Apply general ethical rules and rules of scientific conduct to the assigned tasks.	Make decisions in line with ethical norms and with regard to civic responsibility, and contribute to local communities and organisations according to own competence.
IV. Can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences	**7. Communication**	Describe different methods and tools of communication.	Present complex information in a concise manner orally and in writing.	Evaluate scientific material, communicate it orally and in writing in language appropriate for the audience.
	8. Project Management and Teamwork	Describe strategies for project work and demonstrate attitude to work collaboratively.	Organize and complete a simple project individually or in team.	Identify and implement an appropriate strategy to carry out a simple individual or group project, collaborate constructively, exercise some initiative and acknowledge accountability for the assigned tasks.
V. Have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy	**9. Professional development**	Identify relevant competences needed for pursuing further studies (career goals), as well as personal strengths, weaknesses and attitudes.	Organise own study and/or learning process, using different kinds of learning materials; evaluate personal work and search for information and support.	Enter new fields of study through a positive attitude, evaluate own personal and professional competences and take responsibility for own learning.

TUNING Qualifications Reference Framework General Descriptors of a Master Programme in the Subject Area of PHYSICS (LEVEL 7)

QF EHEA 2nd cycle descriptors	SQF domain dimensions Level 7 (MASTER)	EQF descriptor Knowledge Level 7 *- Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research* *- Critical awareness of knowledge issues in a field and at the interface between different fields*	EQF descriptor Skills Level 7 *- Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields*	EQF descriptor Autonomy and Responsibility (Wider Competences) Level 7 *- Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches* *- Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams*
I. *Have demonstrated knowledge and understanding that is founded upon and extends and/or enhances that typically associated with Bachelor's level, and that provides a basis or opportunity for originality in developing and/or applying ideas, often within a research …*	**1. Theories and models**	Describe the concepts, laws, models, theories and limitations of classical physics and those of at least one of the specialised cores of modern physics, as well as their application across a wide range of real-life situations and different disciplines.	Use concepts, laws and theories from different domains of physics to model, analyse and explain a wide range of physical phenomena and observations.	Identify relevant theories and models required to interpret phenomena, observations, and real-life situations, also in the context of a different discipline, integrating concepts from different domains of classical and modern physics and recognising the limitations of the different theories and models.
II. *Can apply their knowledge and understanding, and problem solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study*	**2. Mathematical methods**	Name and describe standard and advanced mathematical (analytical and numerical) tools and methods and their application in the context of physics theories.	Apply standard and advanced mathematical (analytical and numerical) tools and methods to solve problems in physics.	Identify, adapt, integrate and employ both standard and advanced mathematical (analytical and numerical) tools and methods to solve problems and model situations in a variety of contexts.
	3. Experimental design and scientific investigation	Describe standard and advanced experimental methods, instrumentation, techniques, theories and regulations used in experimental physics.	Design a complete physics experiment, using standard and advanced instrumentation safely and applying a wide range of methods, techniques and theories for data collection, analysis and reporting.	Set up and carry out scientific investigations independently and safely.
	4. Problem solving	Link concepts and laws from various domains of physics with advanced strategies, procedures, tools and criteria for framing, representing, solving and validating the results of a problem.	Categorise problems based on physical principles, including complex problems, context-rich problems, and problems derived from unfamiliar contexts; analyse a complex problem, recognise its structure and devise a creative plan for its solution, execute the devised plan and check for its validity.	Address complex problems and situations from the point of view of physics, identifying the laws and concepts that apply even in unfamiliar situations, devise and carry out a creative plan for reaching a solution and check its validity.
III. *Have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited …*	**5. Scientific culture**	Recall focused historical and epistemological facts on the conceptual development of physics theories and relate them to changes and/or issues in technology, society, and the rules of the scientific community.	Select and use different sources of information on the history, epistemology and current development of physics, and analyse different examples also in relation to technological and societal issues.	Identify common ideas and approaches in different areas of science also in relation to its historical and epistemological evolution, and address scientific, technological and societal issues with an informed scientific, historical and epistemological approach.
	6. Work ethic and integrity	State general and specific ethical principles, norms, values, and standards relevant to the work of a physicist, and illustrate different examples when physics influences health, environment, politics and/or society.	Apply agreed ethical rules and rules of scientific conduct to behaviour in the profession.	Make decisions in line with ethical norms also in research environments and take responsibility for them, and actively contribute to local, national and international communities and (political) organisations according to own competence.
IV. *Can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences clearly and unambiguously*	**7. Communication**	Describe the different channels and tools of communication and their limitations.	Communicate effectively to present complex information in a concise manner orally and in writing and using ICT and technical language appropriate for the audience.	Evaluate scientific material and communicate it to a variety of audiences to inform, influence and debate using various techniques and technical language appropriate for the audience.
	8. Project Management and Teamwork	Describe different project management tools.	Engage productively in an individual or group project.	Identify and implement an appropriate strategy to carry out an articulated individual or group project, collaborate constructively, perform leading and/or supervisory functions when needed, and take responsibility for the assigned tasks.
V. *Have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous*	**9. Professional development**	Identify relevant competences needed for continuing academic/professional development, as well as personal strengths, weaknesses and attitudes.	Organise own study and/or learning process, using different kinds of learning materials; link personal strengths and weaknesses to learning goals and search for learning/career development opportunities.	Enter new fields/environments of study or work through a positive attitude, evaluate own personal and professional competences and take responsibility for continuing academic/professional development, also in unfamiliar contexts

The Tuning - CALOHEE Physics Subject Area Group

The Physics SAG was co-ordinated by Ornella Pantano and Fernando Cornet, who have edited the brochure. The SAG members listed below have all contributed.

Co-ordinators	
Italy Ornella Pantano University of Padova	**Spain** Fernando Cornet Universidad de Granada
Inner Circle	
Belgium Katrien Strubbe Ghent University	**Denmark** Ian Bearden University of Copenhagen
Finland Inkeri Kontro University of Helsinki	**France** Pierre Désesquelles Université Paris-Sud
Greece Evangelos E. Vitoratos University of Patras	**Ireland** Eileen Armstrong Higher Institute of Technology, Sligo
Germany David Buschhüter University of Potsdam	**Hungary** István Groma Eötvos Loránd University
The Netherlands Hay Geurts Radboud University Nijmegen	**The Netherlands** Gerard Barkema Utrecht University
Portugal Maria-José BM de Almeida Coimbra University	**Romania** Sebastian Popescu Alexandro Ioan Cuza University of Iasi
United Kingdom Peter Main King's College London	**EU** European Students' Union Adam Harchi

Outer Circle	
Italy University of Bologna (Olivia Levrini)	**Italy** University of Roma 3
Italy University of Trieste	**Poland** Jagellonian University Krakow
Portugal Porto School of Engineering	**Turkey** Cukurova University

We also acknowledge the contribution of Dr Marta Carli and Dott. Stefania Lippiello (Padova University) to the editing of this brochure, as well as the work of the SAG who generated the first edition of the *Guidelines* in 2007 (see Annex 1).

Guidelines and Reference Points for the Design and Delivery of Degree Programmes in Physics

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1. General Introduction

Tuning Guidelines and Reference Points 2018 for the Design and Delivery of Degree Programmes in Physics is a new edition of a document published in 2008 [2]. Prepared by an international group of academics and validated by independent international peers, this publication has proven its importance as a primary source of information and a stimulus for reflection among stakeholders.

An update is now necessary: both the subject area and society have changed considerably in recent years. Since this brochure serves as an international reference point for an academic discipline in the European Higher Education Area (EHEA) framework, it is essential that it represents the current state of affairs. These *Guidelines* now concerns not only degree profiles and the tasks and societal roles graduates will take on, but also how different degrees fit into the wider context of overarching qualifications frameworks. In other words, which are the essential elements that constitute a particular subject area in higher education? Among other aspects, these *Guidelines* include general descriptors for the first and the second cycle, the bachelor and master, presented in easy-to-read tables, and are meant to be used as reference points for the design and delivery of individual degree programmes. According to the Tuning philosophy, each degree programme has its own unique profile, based on the mission of the institution and taking into account its social-cultural setting, its student body, and the strengths of its academic staff.

The *Guidelines and Reference Points* are the outcome of a long and intense collaboration, starting in 2001, in conjunction with the early phases of the Bologna Process, which has now come to include 48 European countries. They are a result of the grassroots university-driven initiative called *Tuning Educational Structures in Europe*, or simply 'Tuning', that aims to offer a universally useful approach to the modernisation of higher education at the level of institutions and subject areas. The Tuning initiative has developed a methodology to (re-) design, develop, implement and evaluate study programmes for each of the Bologna cycles. Validated in 2007-2008 by a large group of respected academics from numerous academic sectors it still stands.

The Tuning methodology is based on the student-centred and active learning approaches it has promoted since its very launch. Tuning's mission is to offer a platform for debate and reflection which leads to higher education models able to ensure that graduates are well prepared for their societal role, both in terms of employability and as citizens. Graduates need to have obtained as the outcome of their learning process the optimum set of competences required to execute their future tasks and take on their expected roles. As part of their education graduates should have developed levels of critical thinking and awareness that foster civic, social and cultural engagement.

Using the Tuning reference points makes study programmes comparable, compatible and transparent. They are expressed in terms of learning outcomes and competences. Learning outcomes are statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience. According to Tuning, learning outcomes are expressed in terms of the *level of competence* to be obtained by the learner. Competences represent a dynamic combination of cognitive and meta-cognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values. Fostering these competences is the object of all educational programmes. Competences are developed in all course units and assessed at many different stages of a programme. Some competences are subject-area related (specific to a subject area), others are generic (relevant for many or all in degree programmes). According to the Tuning philosophy, subject specific competences and generic competences or general academic skills should be developed together. Normally competence development proceeds in an integrated and cyclical manner throughout a programme.

The initial core competences of the subject area were identified in a consultation process involving four stakeholder groups - academics, graduates, students and employers - during the period 2001-2008. Since then similar consultation processes have been organised in many other parts of the world: these have been taken into consideration in developing this new edition [2-4]. This edition has been elaborated as part of the CALOHEE project (*Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe*), co-financed and strongly supported by the European Commission as part of its Action Programmes for Higher Education. CALOHEE project aims to develop an infrastructure which allows for comparing and measuring learning in a (trans)national perspective. Besides updating and enhancing the reference points brochures it has also developed Assessment Reference Frameworks which offer even more detailed descriptors than those presented in this document.

To make levels of learning measurable, comparable and compatible across Europe academics from the single subject areas have developed cycle (level) descriptors expressed in terms of learning outcomes statements. In this edition, for the first time these are related one-to-one to the two overarching European qualifications frameworks, the 'Bologna' Qualifications Framework for the EHEA (QF for the EHEA) [5] and the EU European Qualifications Framework for Lifelong Learning (EQF for LLL) [6]. In the CALOHEE project these two meta-frameworks have been merged into one model to combine 'the best of two worlds'. While the EQF for LLL is focused on the application of knowledge and skills in society, the focus of the QF for the EHEA is more related to the learning process itself: it applies descriptors which cover different areas or 'dimensions' of learning: knowledge and understanding, application of knowledge and understanding in relation to problem solving, making judgments, communicating information and conclusions, and finally, knowing how to learn.

In developing the CALOHEE Tuning model, we realised that 'dimensions' are an indispensable tool, because they make it possible to distinguish the principal aspects that constitute the subject area. Dimensions help give structure to a particular sector or subject area and also make its basic characteristics more transparent. Furthermore, the 'dimension approach' is complementary to the categories included in the EQF for LLL, which uses the categories of knowledge, skills and competences to structure its descriptors. Thus, in CALOHEE terms, the three columns correspond to a 'knowledge framework', a 'skills framework' and a 'competency framework', linked by level. The last column, the 'competency framework', refers to the wider world of work and society and identifies the competences required to operate successfully in the work place and as a citizen. It builds on the first two elements: knowledge and understanding and the skills necessary to develop and apply this knowledge.

In addition to addressing cycle-level descriptors, Tuning has given attention to the Europe-wide use of the student workload based European Credit Transfer and Accumulation System (ECTS) to ensure the feasibility of student-centred degree programmes. Some ten years ago it transformed the original credit transfer system into a transfer and accumulation system. According to Tuning, ECTS not only allows student mobility across Europe and in other countries as well; it can also facilitate programme design and development, particularly with respect to coordinating and rationalising the demands made on students by concurrent course units. In other words, ECTS permits us to plan how best to use students' time to achieve the aims of the educational process, rather than considering teachers' time as the primary constraint and students' time as basically limitless.

The use of the learning outcomes and competences approach implies changes regarding the teaching, learning and assessment methods. Tuning has identified approaches and best practices to form the key generic and subject specific competences. Some examples of good practice are included in this brochure. More detailed examples can be found in the subject area based Assessment Frameworks.

Finally, Tuning has drawn attention to the role of quality in the process of (re-)designing, developing and implementing study programmes. It has developed an approach for quality enhancement which involves all elements of the learning chain. It has also developed a number of tools and identified examples of good practice which can help institutions to improve the quality of their degree programmes.

This publication reflects the outcomes of the work done by the Subject Area Group (SAG) in Physics which was established in the context of the CALOHEE project. The names of the members of the previous SAGs appear in an appendix. The outcomes are presented according to a template used for all Tuning Guidelines and Reference Points brochures to facilitate readability and rapid comparison across the subject areas. It aims to provide, in a succinct manner, the basic elements for a quick introduction into the subject area. It shows in synthesis the consensus reached by a subject area group after intense and lively discussions in the group. The more ample documents on which the template is based are also included in the brochure. They give a more detailed overview of the SAG's conclusions.

We hope that this publication will be of interest to many, and look forward to receiving comments and suggestions from the stakeholders, in view of further improvement.

Tuning-CALOHEE Management Team,
Robert Wagenaar, CALOHEE project-coordinator

2. The Physics Subject Area

2.1. Physics

As the starting point for structuring the Tuning Subject Area Qualifications Reference Framework (Meta-Framework) and as a follow-up the Tuning-CALOHEE Assessment Reference Framework for Physics, the SAG analysed the specificity of the Physics Subject Area. Besides personal experience of the SAG members, a good reference for this chapter were the Specifications for Physics bachelor and master studies by the European Physical Society [7, 8].

Physics is concerned with the observation and quantitative description of natural phenomena and human-made systems on the basis of reproducible experimental findings and rigorous mathematical tools. It is one of the most fundamental scientific disciplines, and the one which deals with the most profound question about our universe. Physics is also strictly involved with the cultural, societal and technological issues of our time, since new ideas and discoveries in physics often have a large impact on their development.

Through its inclusion of astronomy, physics is also one of the oldest academic disciplines. It also provides a conceptual basis for other branches of Science (Chemistry, Biology, Geology, etc.) and other related disciplines (Computer Science, Engineering, Medicine, etc.) in such a way that curricula in those field often include physics courses and interdisciplinary courses like biophysics or geophysics are increasingly offered by universities around the world.

Physics is both an experimental and a theoretical discipline. Direct observation and measurements are an integral part of physics, and agreement with experiment constitutes the final test of the validity of any physics theory. Physics theories, on the other hand, are based on models rigorously described by mathematics equations and sensible assumptions, and their speculative results are compared with experimental observation.

Physics also has a strong bound with technology, since many physics discoveries have led to relevant technological innovations and revolutions, and vice versa different technological innovations have enabled advancements in physics. Among these, information technology (IT) play a distinct role, so that computational physics is sometimes regarded as a third branch of physics besides experimental and theoretical physics.

Physics is often regarded as a ‘hard’, eminently analytical science. However, it should be kept in mind that progress in physics inevitably requires imagination and creativity. Dealing with unanswered, profound questions and finding new approaches to solving experimental or theoretical issues requires a great flexibility of the mind. Moreover, it is often the collaboration between physicists with different backgrounds and the exchange of ideas and techniques with people from other disciplines that enable the major physical and scientific discoveries of our days.

2.2. Physics graduates

Given the dual (experimental and theoretical) nature of physics, acquaintance with practical work and experimental design on one side and with the use of mathematics and IT on the other is an essential part of the profile of a physics graduate. Such competences constitute the core of the profession and entail the development of both generic and subject-specific competences, which endow the graduate with a flexible mind and the ability to approach increasingly complex systems, even outside the realm of physics.

Indeed, physics provides an extraordinarily rich package of transferable skills. Physics graduates are eligible for a great variety of jobs, from research careers to industry, and increasingly in emerging areas such as business and finance. This is due to their capability to enter new fields and learn with autonomy, and to their strong modelling, computing and analysis skills. Physicists are good at framing problems and solving them, can communicate complex ideas, and have developed critical thinking through the use of a scientific habit of mind in a variety of situations.

Physics is a demanding discipline. An understanding of the frontiers of physics requires advanced knowledge, some of which cannot be fully acquired during a bachelor or even master degree programme. This is why the physics learning path requires an ordered approach in the learning progression, starting with a strong base in mathematics in the first cycle to more advanced subjects in the following cycles. This is also a main reason why physics is a subject where a large majority of graduates continue their studies at the third cycle, probably more than any other subject. As a consequence, degree courses in physics must be flexible enough to enable both research- and job-oriented careers.

2.3. Physics and physics graduates in Europe

Physics is a major discipline in the European Higher Education Area (EHEA). The role played by physics graduates in the EU economy is relevant, with many professionals required for scientific and technical positions not only in the strict domain of physics but also in other areas. Moreover, physics is also one of the main columns of the European culture, as it is an essential part of our understanding of the universe and has deeply influenced the cultural and societal development of our world. Whilst the foundations of physics education remain deeply rooted in history, physics degrees continue evolving in response to developments in the discipline, society, and the job market both in EU and in a worldwide perspective.

An important aspect of the physics community is its international character, in both research and education. This suggests the need and at the same time the opportunity for physics students to be mobile during their learning path, almost compulsorily in the final cycles. For this reason, mobility and exchange programs between European countries should continue to play a major role in physics HE programmes.

2.4. Physics degree programmes offered by European universities

Physics-based degree courses are present in European universities with two main approaches:

A. Degree courses entirely focussed on Physics since the beginning;

B. Degree courses where the initial years of the programme are common to different branches of Science, and only later students can choose Physics as their majoring subject.

Physics degrees are usually offered within the faculty of Science. In other cases, the offer of a degree course in Applied Physics or similar occurs within the faculty of Engineering. Physics is also one of the majoring subjects in a number of interdisciplinary or cross-department courses, either of recent implementation or traditionally linked to physics. Examples of such degree courses are *Astronomy*, *Optics and Optometry*, *Mathematics and Physics*. Moreover, physics departments often offer course units in physics for a number of degree courses of the same universities, mostly in the faculties of Science and Engineering.

To further characterise physics-based degree programmes typically offered by European universities, a survey was conducted that involved 18 European HE institutions in the following countries: BE, ES, D, FI, FR, HU, IE, IT (3 Universities), NL, PL, PT, TR, UK. Most of these HE institutions characterised themselves as 'comprehensive universities', meaning that they offer a wide range of undergraduate and graduate programmes besides having a significant research activities. A smaller portion of the sample defined themselves as 'research universities', meaning that they mainly offer graduate, research-oriented programmes and a smaller range of undergraduate programmes. This variety of situations is grafted into the context of the implementation of the Bologna process across European countries. For this reason, the survey considered typical indicators that are used when analysing the Bologna process implementation, namely the implementation of two-level programmes, the use and quantification of ECTS, the definition of learning outcomes, and mobility. Since the focus of the CALOHEE project was on learning outcomes, we analysed this aspect more in detail, also gathering information about the structure and content of the physics programmes.

Concerning the implementation of two-level programmes and the quantification of ECTS, most of the universities provide two-level programmes according to the Bologna guidelines. Bachelor degrees offered in these institutions usually cover 180 ECTS (the rest being composed of 240 ECTS) while the master level programmes usually cover 120 ECTS. Bachelor programmes are usually characterised as 'specialised' programmes focussing mainly or only on physics, but there are also examples of broad programmes covering elements of different science-related topics followed by a later specialisation in physics, or cross-cutting programmes that cover also subjects from a different sector, such as philosophy. Most programmes do not distinguish between different tracks at the bachelor level, but some institutions report that their offer includes different degree courses, some of which are job-oriented (e.g. *Optics and Optometry* or *Applied Physics*). Most programmes however include minor or elective subjects, which can be taken within or outside the same faculty and can cover a variable number of ECTS depending on the institution. Some programmes also include a work-based learning component like work placement or traineeship. A final thesis is required in the vast majorities of the institutions. For the master level, most programmes are specialised ones, and different tracks can be distinguished. These tracks often correspond to the specialised cores of physics (e.g. Theoretical Physics, Astrophysics, Condensed Matter Physics, etc.), but there are also interdisciplinary or job-oriented courses. Almost all master-level programmes include elective subjects, which can be usually be taken also outside the faculty, and some programmes also include a work-based learning component of variable ECTS size. A final thesis is required in the vast majorities of the institutions. As for mobility, most universities do not include a compulsory or clearly defined mobility window for their students, neither at the bachelor nor at the master level. Concerning learning outcomes, most universities state their programmes are based on well-defined aims and objectives, learning outcomes, and competence statements for both levels. However, it seems from the responses that there is some confusion about the use of the terms. Finally, bachelor and master programmes can be mainly described as traditional programmes focussed on knowledge acquisition and transfer; these programmes are largely based on lecture classes, which might be supported by seminar groups and laboratory work. Some institutions however offer student-centred[1] and/or research-based programmes requiring active student learning, mainly based on a seminar/exercise course unit model and extended laboratory work.

[1] Definition of student-centred learning according to the European Student Union (ESU 2010): A learning approach characterised by innovative methods of teaching which aim to promote learning in communication with teachers and students and which takes students seriously as active participants in their own learning, fostering transferable skills such as problem-solving, critical and reflective thinking.

The following table summarises the courses offered by the HE institutions in the sample.

Level	Typical degrees
Bachelor (Level 6 EQF)	Typical names of Bachelor programmes are: *Physics, Astronomy, Physics and Astronomy.* Some institutions have different or more specific Master programmes, such as: *Science, Mathematics and Physics, Physics with a Year Abroad, Physics with Theoretical Physics, Physics with Medical Applications, Mathematics and Physics, Physics and Philosophy, Optics and optometry, Biomedical Devices, Medical Biotechnology, Forensic Investigation and Analysis, Science for GMP.*
Master (Level 7 EQF)	Typical names of Master programmes are: *Physics, Astronomy, Physics and Astronomy.* Some institutions have different or more specific Master programmes, such as: *Science, Astrophysics and Space Instrumentation, Physics and Mathematics, Integrated Master in Physical Engineering, Geophysics and Meteorology, Physics and Chemistry Teaching, Integrated Master in Biomedical Engineering, Physics of the Earth System, Physics of the Universe, Physics of Data, MSci Physics*, MSci Physics with Theoretical Physics*, MSci Mathematics and Physics*, MSc Physics*.* (*Note: In UK, the MSc course is a one year, stand-alone programme. The MSci courses are 'integrated masters' programmes, i.e. 4 year integrated programmes starting from the same point as the BSc programmes but the students graduate with a Master degree. Such degrees are available in all UK Physics departments.)

2.5. Typical occupations of physics graduates

Employability of graduates, also after completion of a bachelor-level degree, is considered another indicator of the implementation of the Bologna process. In order to achieve this, attention must be paid to the integration of key ('generic') competences into the curriculum, such as language skills, communication skills, and project management skills.

In section 2.3 we have outlined the profile of physics graduates, highlighting their rich package of transferable skills which make them eligible for a variety of careers. On the other hand, we have discussed how the nature of physics studies makes it one of the subjects where the largest number of students aims for a job in research, with the consequence that many students in fact continue to study to the second and third cycle, with a higher proportion compared to students in other subject areas.

The survey mentioned above also aimed to gather information about the typical careers pursued by physics graduates. First of all, HE institutions were asked to state which key ('generic') competences their physics students were expected to achieve at the end of their bachelor or master programmes. A common core of competences was identified, with some difference in their rating order between the bachelor and master level. HE institutions participating in the survey were also asked to indicate the typical sectors where physics graduates are employed, with examples of specific jobs and tasks. Noteworthy, many universities report that 90-95% of their bachelor graduates actually continue their studies as master students. However, different possible employability sectors were indicated for bachelor graduated as well, indicating the importance of a good identification of the knowledge, skills and competence of these graduates as well. This process of identifying core competences and roles expected from physics graduates as perceived by European HE institutions was a major part of the consulting process that led to the identification of the dimensions and sub-dimensions of the CALOHEE Assessment Reference

Framework for Physics. The table below summaries the core competences, the sectors of employability, occupations and tasks of physics graduates as described by the outcomes of the CALOHEE survey.

Common core of competences of Physics graduates		
Abstract and analytical thinking; Problem solving; Collect, select, process and analyse information; Information and communication technologies (ICT); Oral communication; Creativity; Learn-to-learn and stay up-to-date with learning; Teamwork; Critical and self-critical awareness; Planning and time management; Project design and management.		
Sectors of employment of Physics graduates		
Sector	**Occupation**	**Tasks**
Research	Research assistant (BA), PhD student (MA), researcher (MA)	Writing papers and reports, literature search, preparing presentations, designing and carrying out experiments, modelling, numerical and analytical analysis, calibration and measurement, data collection and analysis, design, test and use technical instrumentation, team work and management
Industry	R&D, technician, manufacturer (BA), optician/optometrist (BA), entrepreneur, product engineer, quality controller, model developer	Developing new technologies and materials, design, test and use technical instrumentation, product development, quality control, technical assistance, data collection and analysis, project management, administrative tasks, writing technical reports
ICT	Programmer, software engineer, data analyst, web developer	Software development, numerical analysis, product development, technical assistance
Finance and insurances	Banker (BA), financial analyst, investment expert, credit risk analyst, insurance consultant	Analytical modelling, numerical analysis and modelling, consulting, administrative tasks
Business and management	Management consultant, project manager, sales manager, marketing director	Analytical modelling, numerical analysis and modelling, consulting, administrative tasks, team management
Education (teacher)	Teaching assistant, science/physics teacher at secondary and high schools	Teaching, writing reports, planning and testing education programmes, team work and management
Culture	Media executive, communication, scientific journalist	Scientific advice and information, writing and communicating, team work
Health	Medical/clinical physicist	Scientific advice, equipment design/testing, inspection and quality control, team work and management, writing reports
Government/organisations	Government officer, consultant, policy advisor (MA)	Scientific advice and information, writing reports, (complex systems) modelling

3. The Tuning-CALOHEE Assessment Reference Framework for Physics

3.1. General structure of the Framework

In the Tuning approach, an Assessment Reference Framework provides a complete overview of a subject area formulated in terms of learning outcomes. A learning outcome is a measurable result of a learning experience, which allows assessing to what extent a piece of knowledge, a skill or a competence has been developed. Learning outcomes should be clearly and precisely formulated in order to guarantee objectivity and transparency. Tuning has developed a model, related to the work of Bloom, Biggs and others, that helps in elaborating reliable statements [9]. Other works have highlighted the importance of using appropriate verbs to formulate level descriptors [10].

In Tuning-CALOHEE Assessment Reference Frameworks, learning outcomes are formulated within different 'dimensions', which are the main building blocks of the subject area and can be related to the more general QF-EHEA dimensions according to the model described in Chapter 1. Each dimension is then broken down into 'sub-dimensions' which describe the key elements of that dimension in greater detail. The descriptors of these sub-dimensions are the 'real' learning outcomes, since they meet the condition of being measurable and indicating not only the subject, but also its context and complexity. For each dimension and sub-dimension, LOs are described according to the three EQF categories 'Knowledge', 'Skills' and 'Autonomy and responsibility'.

The Tuning-CALOHEE Assessment Reference Framework for Physics follows the general structure of Tuning-CALOHEE Assessment Frameworks outlined above. Two assessment framework have been developed, covering the first (bachelor) and second (master) level of higher education (EQF levels 6 and 7) respectively.

3.2. Process for the development of the Tuning-CALOHEE Assessment Reference Framework for Physics

In the development of the Tuning-CALOHEE Assessment Reference Framework for Physics, the SAG started from the common structure adopted in the CALOHEE project that is the two-dimensional template obtained by merging the Qualifications Framework for the European Higher Education Area and the European Qualifications Framework for Life Long Learning. After reflecting on the characteristics of the physics subject as described in Chapter 2, we analysed the learning outcomes for Physics described in previous Tuning works [2-4] as well as other national and international documents such as the *Subject Benchmark Statement* produced by the Quality Assurance Agency for Higher Education of the UK (2017) [11]. In this process, a great importance has been given to the relationship between specific and generic competences and to the need of framing the latter in the context of physics. The SAG agreed that a degree course should provide students not only with subject-specific content but also with the competences needed for effective civic, social and cultural engagement. For this purpose, we referred to the four dimensions of the CALOHEE framework for civic, social and cultural engagement (see Annex 2) and we attuned them to the context of the subject area. As a result of this process, the SAG identified an initial set of 14 dimensions that were matched to the QF dimensions as summarised in the following table.

Dimensions of the QF for the EHEA	Original dimensions of the CALOHEE Assessment Reference Framework for Physics
I) Knowledge and Understanding	1.Knowledge and understanding 2.Mathematical methods
II)Applying Knowledge and Understanding	3.Experimental design 4.Problem solving
III) Making Judgement	5.Scientific culture 6.Interdisciplinarity 7.Ethical awareness 8.Management
IV)Communication Skills	9.Communication 10.Teaching 11.Teamwork
V)Learning skills	12.Literature search 13.Lifelong learning 14.Professional development

A deeper analysis of the initial set of dimensions suggested reducing the total number of dimensions to 9 by grouping some of them. The final dimensions of the CALOHEE Assessment Reference Framework for Physics are reported in the table below, together with their correspondence with the dimension of the QF-EHEA.

Dimensions of the QF for the EHEA	Final dimensions of the CALOHEE Assessment Reference Framework for Physics
I) Knowledge and Understanding	1.Theories and models 2.Mathematical methods
II) Applying Knowledge and Understanding	3.Experimental design and scientific inquiry 4.Problem solving
III) Making Judgement	5.Scientific culture 6.Work ethic and integrity
IV) Communication Skills	7.Communication 8. Project management and teamwork
V) Learning skills	9.Professional development

3.3. Learning outcomes of the Tuning-CALOHEE Assessment Reference Framework for Physics

As mentioned above, central to the Tuning approach is the formulation of level descriptors in terms of measurable and well-stated learning outcomes. To this goal, each dimension was split into sub-dimensions that describe the core elements of each dimension in greater detail.

CALOHEE Assessment Reference Framework for Physics	
Dimensions	**Sub-dimensions**
1.Theories and models	1.1 Theories and phenomena 1.2 Applications of theories and models
2.Mathematical methods	2.1 Mathematical tools 2.2 Computational tools
3.Experimental design and scientific inquiry	3.1 Experimental design and methodology 3.2 Instrumentation 3.3 Data analysis 3.4 Experiment documentation 3.5 Safety
4.Problem solving	4.1 Problem framing 4.2 Analytical thinking 4.3 Solution procedure and execution 4.4 Validation of results 4.5 Creative and innovative thinking
5.Scientific culture	5.1 History of physics 5.2 Epistemology 5.3 Sources of scientific information
6.Work ethic and integrity	6.1 Ethical rules in the profession 6.2 Awareness of professional actions impact 6.3 Governance and decision making
7.Communication	7.1. Information sources 7.2 Data representation 7.3 Means of communication 7.4 Technical English
8. Project management and teamwork	8.1 Project management tools 8.2 Teamwork 8.3 Organisations, societies and cultures
9.Professional development	9.1 Professional requirements 9.2 Personal capacities and attitudes

For each dimension and sub-dimensions, descriptors were written in the form of learning outcomes. The ‘real’, directly usable learning outcomes are in fact the sub-descriptors (descriptors of a sub-dimensions), because they meet the condition of being measurable and indicating not only a subject, but also its context and complexity. This scheme was then applied for the two levels (bachelor and master), differentiating the descriptors in such a way that the difference between the two levels lies in the degree of specialisation and the depth and complexity of problems, processes, and activities that can be solved, designed, or conducted. We illustrate this difference in the following table, where only the dimension descriptors are reported for the indicator ‘Responsibility and autonomy’.

CALOHEE Assessment Reference Framework for Physics Dimension	LEVEL 6 EQF descriptor 'Responsibility and Autonomy'	LEVEL 7 EQF descriptor 'Responsibility and Autonomy'
1.Theories and models	C6_1 Identify relevant physics theories and models required to interpret phenomena, observations, and real-life situations.	C7_1 Identify relevant theories and models required to interpret phenomena, observations, and real-life situations, also in the context of a different discipline, integrating concepts from different domains of classical and modern physics and recognising the limitations of the different theories and models.
2.Mathematical methods	C6_2 Identify and employ standard mathematical (analytical and numerical) tools and methods to solve problems and model situations.	C7_2 Identify, adapt, integrate and employ both standard and advanced mathematical (analytical and numerical) tools and methods to solve problems and model situations in a variety of contexts.
3.Experimental design and scientific inquiry	C6_3 Set up and carry out simple scientific investigations safely under supervision.	C7_3 Set up and carry out scientific investigations independently and safely.
4.Problem solving	C6_4 Address problems from the point of view of physics, identifying the laws and concepts that apply in a specific situation, devise and carry out a (creative) plan for reaching a solution and check its validity.	C7_4 Address complex problems and situations from the point of view of physics, identifying the laws and concepts that apply even in unfamiliar situations, devise and carry out a creative plan for reaching a solution and check its validity.
5.Scientific culture	C6_5 Identify some common ideas and approaches in different areas of science, also in relation to its historical and epistemological evolution, and evaluate the influence of science on technology and society in some relevant cases.	C7_5 Identify common ideas and approaches in different areas of science, also in relation to its historical and epistemological evolution, and address scientific, technological and societal issues with an informed scientific, historical and epistemological approach.
6.Work ethic and integrity	C6_6 Make decisions in line with ethical norms and with regard to civic responsibility, and contribute to local communities and organisations according to own competence.	C7_6 Make decisions in line with ethical norms also in research environments and take responsibility for them, and actively contribute to local, national and international communities and (political) organisations according to own competence.
7. Communication	C6_7 Evaluate scientific material, communicate it orally and in writing in language appropriate for the audience.	C7_7 Evaluate scientific material and communicate it to a variety of audiences to inform, influence and debate using various techniques and technical language appropriate for the audience.

8. Project management and teamwork	C6_8 Identify and implement an appropriate strategy to carry out a simple individual or group project, collaborate constructively, exercise some initiative and acknowledge accountability for the assigned tasks.	C7_8 Identify and implement an appropriate strategy to carry out an articulated individual or group project, collaborate constructively, perform leading and/or supervisory functions when needed, and take responsibility for the assigned tasks.
9.Professional development	C6_9 Enter new fields of study through a positive attitude, evaluate own personal and professional competences and take responsibility for own learning.	C7_9 Enter new fields/environments of study or work through a positive attitude, evaluate own personal and professional competences and take responsibility for continuing academic/professional development, also in unfamiliar contexts

The full Assessment Reference Framework reported in the following pages is complemented by an overview of the most appropriate learning, teaching and assessment strategies and approaches to achieve the intended learning outcomes. This is in line with the Tuning philosophy that learning, teaching and assessment should be fully aligned.

We hope that this Assessment Reference Framework could serve as a tool for modernising, revising, and enhancing existing physics programmes and to design new ones, as well as a reference for evaluating the completeness and quality of a degree programme, and a reliable instrument for measuring and comparing the achievement of learning outcomes in a national and international setting.

3.4 Tuning-CALOHEE Assessment Reference Framework for Physics – LEVEL 6 EQF

Dimension 1: Theories and models			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_1. Level descriptor Theories and models	**K6_1** **Describe the fundamental concepts, laws, models and theories of classical physics and elements of modern physics, as well as their application across a number of real-life situations.**	**S6_1** **Use physical concepts, laws and theories from various domains of physics to model, analyse and explain simple physical phenomena and problems.**	**C6_1** **Identify relevant physics theories and models required to interpret phenomena, observations, and real-life situations.**
Subset 1 L6_1.1 **Theories and phenomena**	K6_1.1 Name, describe and explain the fundamental laws, theories, and phenomena of classical physics and elements of modern physics.	S6_1.1 Use the fundamental physics theories and models to model and describe a simple physical system, to explain observations and make predictions.	C6_1.1 Identify relevant physical theories that are required to understand a phenomenon or observation.
Subset 2 L6_1.2 **Applications of theories and models**	K6_1.2 Describe and explain how physics is used across a number of real-life applications.	S6_1.2 Apply basic elements of physics to explain simple real-life applications.	C6_1.2 Identify which physics models and theories are relevant in different real-life problems.

Dimension 2: Mathematical methods			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_2. Level descriptor Mathematical methods	**K6_2** **Name and describe standard mathematical (analytical and numerical) tools and methods and their application in the context of physics theories.**	**S6_2** **Apply standard mathematical (analytical and numerical) tools and methods to solve problems in physics.**	**C6_2** **Identify and employ standard mathematical (analytical and numerical) tools and methods to solve problems and model situations.**
Subset 1 L6_2.1 **Mathematical tools**	K6_2.1 Name and describe standard mathematical tools and their application in the context of physics theories.	S6_2.1 Apply standard mathematical tools to model and solve problems in physics and to model physical phenomena.	C6_2.1 Identify and employ the appropriate mathematical tool to model, represent, and/or solve a problem in physics.
Subset 2 L6_2.2 **Computational tools**	K6_2.2 Name and describe standard computational tools used in physics and the basic features of at least one programming language.	S6_2.2 Use basic computational tools (software, programming language) and methods to model and solve problems in physics.	C6_2.2 Evaluate and employ basic computational tools to model, represent, and/or solve a problem in physics.

Dimension 3: Experimental design and scientific investigation			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_3. Level descriptor Experimental design and scientific investigation	**K6_3** **Describe standard methods, instrumentation, techniques, theories and regulations used in experimental physics.**	**S6_3** **Design a simple experimental investigation, using standard instrumentation and follow guidelines, and apply basic methods, techniques and theories for data collection, analysis and reporting.**	**C6_3** **Set up and carry out simple scientific investigations safely under supervision.**
Subset 1 L6_3.1 **Experimental design and methodology**	K6_3.1 Name and describe the basic aspects of a scientific investigation as well as the physical quantities involved in a situation, and describe the inherent physical models or theories.	S6_3.1 Formulate a simple prediction from a hypothesis and devise a plan to test it, and estimate the order of magnitude of the results of an experiment.	C6_3.1 Conduct simple investigations under supervision, identifying the relevant theoretical framework and the process required to obtain consistent results.
Subset 2 L6_3.2 **Instrumentation**	K6_3.2 Name and describe standard instrumentation used in experimental physics and their specifications.	S6_3.2 Set up standard experimental arrangements, identify the specifications of standard instrumentation, use it under supervision and apply simple experimental procedures to gather data.	C6_3.2 Identify, arrange and employ the appropriate instrumentation to carry out an investigation, under supervision and/or in standard situations.
Subset 3 L6_3.3 **Data analysis**	K6_3.3 Name and describe basic methods and standard techniques for the processing of experimental data.	S6_3.3 Organise and analyse experimental data using standard tools and techniques, including basic software; estimate and correctly apply uncertainties to the measurements and evaluate the reliability of the results.	C6_3.3 Process simple sets of experimental data and evaluate the reliability of the results.
Subset 4 L6 _3.4 **Experiment documentation**	K6_3.4 Describe standard methods of recording the details of an experimental activity and storing data.	S6_3.4 Keep a record of the details and steps of an experiment, including the acquisition of data, and write a simple laboratory report.	C6_3.4 Identify the appropriate method to report on an investigation and communicate the results.
Subset 5 L6_3.5 **Safety**	K6_3.5 Describe the main safety issues, equipment and regulations of a standard physics laboratory.	S6_3.5 Follow the safety regulations of a standard physics laboratory, including using basic individual protection equipment.	C6_3.5 Identify the safety regulations of a physics laboratory and operate accordingly, including the use of appropriate protection equipment.

Dimension 4: Problem solving			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_4. Level descriptor Problem solving	**K6_4** **Link physics concepts and laws with basic strategies, procedures, tools and criteria for framing, representing, solving and validating the results of a problem.**	**S6_4** **Categorise problems based on physical principles, analyse a problem, recognise its structure and devise a (creative) plan for its solution, execute the devised plan and check for its validity.**	**C6_4** **Address problems from the point of view of physics, identifying the laws and concepts that apply in a specific situation, devise and carry out a (creative) plan for reaching a solution and check its validity.**
Subset 1 L6_4.1 **Problem framing**	K6_4.1 Organise knowledge of physics principles and theories in a scheme that includes procedures and conditions for their application.	S6_4.1 Categorise problems and situations based on physics principles rather than objects and surface features; apply known procedures and schemata to frame a problem.	C6_4.1 Identify the deep structure of a problem or situation, put it in a physical framework, and identify common structures in different problems.
Subset 2 L6_4.2 **Analytical thinking**	K6_4.2 Recall physics concepts and laws relevant for a problem as well as standard tools and strategies for representing a problem in terms of these concepts.	S6_4.2 Perform a qualitative analysis of a problem before writing equations, recognise the sub-problems or tasks, extract data and unknowns, represent a problem in a convenient way including modelling it with physical concepts, principles and equations, and devise a plan for its solution.	C6_4.2 Address problem situations analytically, recognising the different elements and tasks, and identify a way of modelling a problem as well as a strategy to tackle it.
Subset 3 L6_4.3 **Solution procedure and execution**	K6_4.3 Recall standard mathematical (analytical and numerical) tools relevant for the problem as well as the rules and procedures to use them.	S6_4.3 Execute the devised plan and apply the appropriate mathematical tools to reach the solution of the problem.	C6_4.3 Carry out a plan identifying the best tools to fulfil it.
Subset 4 L6_2.4 **Validation of results**	K6_4.4 Recall some standard criteria for stating the validity of a result.	S6_4.4 Apply standard criteria to check the validity of the solution and/or intermediate outcomes, e.g. evaluating the expected order of magnitude and units.	C6_4.4 Evaluate a process and its results, admitting the possibility of mistakes.
Subset 5 L6_4.5 **Creative and innovative thinking**	K6_4.5 Organise knowledge of physics in a way that facilitates links between different concepts and ideas.	S6_4.5 Reflect on own solution to a problem and compare it with others' solutions; acknowledge alternative ways to look at a same problem.	S6_4.5 Devise creative ways to address a problem, issue or task, and to exit critical issues or stuck situations.

Dimension 5: Scientific culture			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_5. Level descriptor Scientific culture	**K6_5** **Describe the main traits of the historical and epistemological development of physics and relate them to changes and/or issues in technology, society, and the rules of the scientific community.**	**S6_5** **Select with guidance and use sources of information on the history and current development of physics and on epistemology, and analyse some relevant examples also in relation to technological and societal issues.**	**C6_5** **Identify some common ideas and approaches in different areas of science also in relation to its historical and epistemological evolution, and evaluate the influence of science on technology and society in some relevant cases.**
Subset 1 L6_5.1 **History of physics**	K6_5.1 Recall the main traits of the historical evolution of physics, also in relation to technological and societal changes.	S6_5.1 Select with guidance and use sources of information on the history of physics, and analyse some relevant examples also in relation to technological and societal issues.	C6_5.1 Identify some common ideas and approaches in different areas of physics with reference to its history and evaluate the influence of physics on technology and society in some relevant cases.
Subset 2 L6_5.2 **Epistemology**	K6_5.2 Outline the dominant epistemological schemes that have influenced the development of physics theories.	S6_5.2 Utilise the epistemological schemes shared by the scientific community to address problems and issues in physics.	C6_5.2 Adopt an epistemological perspective in addressing scientific problems.
Subset 3 **L6_5.3** **Sources of scientific information**	K6_5.3 Name the procedures used by the scientific community to validate scientific works and describe the criteria for selecting reliable scientific information from libraries or the Internet.	S6_5.3 Search for and use scientific information from technical literature under supervision, and duly cite it when necessary.	C6_5.3 Identify reliable sources of information concerning scientific issues.

Dimension 6: Work ethic and integrity			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_6. Level descriptor Work ethic and integrity	**K6_6** **State general ethical principles, norms, values, and standards relevant to the work of a physicist, as well as some examples when physics influences health, environment, politics and/or society.**	**S6_6** **Apply general ethical rules and rules of scientific conduct to the assigned tasks.**	**C6_6** **Make decisions in line with ethical norms and with regard to civic responsibility, and contribute to local communities and organisations according to own competence.**
Subset 1 L6_6.1 **Ethical rules in the profession**	K6_6.1 Recall the ethical rules and standards applied in the profession.	S6_6.1 Apply general principles, norms, values and professional standards to the assigned tasks.	C6_6.1 Contribute to promoting and defending general ethical principles, norms, values and professional standards.
Subset 2 L6_6.2 **Awareness of professional actions impact**	K6_6.2 Recall some examples when your actions as a physicist affect health, environment and/or society.	S6_6.2 Acknowledge the consequences of own professional actions and estimate the impact of the main technological applications of physics on individuals, environment and society.	C6_6.2 Accept accountability for own professional actions and make decisions in line with the ethical norms and societal implications.
Subset 3 L6_6.3 **Governance and decision making**	K6_6.3 Recall some examples when physics theories and results affect (political) decisions and policy making.	S6_6.3 Conduct informed processes of decision making on the assigned tasks.	C6_6.3 Contribute to and with communities and (political) organisations with own competence.

Dimension 7: Communication			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_7. Level descriptor Communication	**K6_7** **Describe different methods and tools of communication.**	**S6_7** **Present complex information in a concise manner orally and in writing.**	**C6_7** **Evaluate scientific material, communicate it orally and in writing in language appropriate for the audience.**
Subset 1 L6_7.1 **Information sources**	K6_7.1 Describe the main features of the processes of information and communication.	S6_7.1 Evaluate the way in which sources of evidence, data, and expert opinions are used in various media.	C6_7.1 Actively contribute to societal debates using reliable data and information sources.
Subset 2 L6_7.2 **Data representation**	K6_7.2 Describe different representations of data (words, graphs, tables, animations, etc.)	S6_7.2 Use different representation of data.	C6_7.2 Compare and identify the appropriate representation of data for presentations to peer groups.
Subset 3 L6_7.3 **Means of communication**	K6_7.3 Describe and explain the role of different means of communication (scientific magazines, books, newspapers, videos, web, etc.)	S6_7.3 Produce simple scientific reports and oral presentations, using appropriate technical language.	C6_7.3 Identify and choose the appropriate writing or oral style according to the context and communicative goals (laboratory report, dissertation, scientific articles, etc.).
Subset 4 L6_7.4 **Technical English**	K6_7.4 Demonstrate a working knowledge the English language at the level necessary for basic physics communication.	S6_7.4 Read, speak, write in technical English.	C6_7.4 Study and communicate specific physics topics in technical English (minimum B1 level of Common European Framework of Reference for Languages).

Dimension 8: Project Management and Teamwork			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_8. Level descriptor Project Management and Teamwork	**K6_8** **Describe strategies for project work and demonstrate attitude to work collaboratively.**	**S6_8** **Organize and complete a simple project individually or in team.**	**C6_8** **Identify and implement an appropriate strategy to carry out a simple individual or group project, collaborate constructively, exercise some initiative and acknowledge accountability for the assigned tasks.**
Subset 1 L6_8.1 **Project management tools**	K6_8.1 Recall some strategies for planning, organising, checking progress, and evaluating results of a project.	S6_8.1 Use appropriate tools, set targets, and organise work to meet deadlines.	C6_8.1 Take responsibility for contributing in a simple individual or group project.
Subset 3 L6_8.2 **Teamwork**	K6_8.2 Describe and characterise the different components of an effective teamwork.	K6_8.2 Listen, share opinions and respectfully participate in conversation and/or discussion activities, and use (receive and give) feedback.	K6_8.2 Identify own and others' competences and roles with respect to teamwork, contribute constructively and respectfully in a group, and take responsibility for own task(s).
Subset 2 L6_8.2 **Organisations, societies and cultures**	K6_8.3 Recognise the main differences in and between individuals, organisations, societies and cultures.	S6_8.3 Analyse some relevant issues and/or potential conflicts in and between individuals, organisations, societies and (work) cultures.	C6_8.3 Identify best practices and interventions in the case of tensions and conflicts.

Dimension 9: Professional development			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L6_9. Level descriptor Professional development	**K6_9.** **Identify relevant competences needed for pursuing further studies (career goals), as well as personal strengths, weaknesses and attitudes.**	**S6_9** **Organise own study and/or learning process, using different kinds of learning materials; evaluate personal work and search for information and support.**	**C6_9** **Enter new fields of study through a positive attitude, evaluate own personal and professional competences and take responsibility for own learning.**
Subset 1 L6_9.1 **Professional requirements**	K6_9.1 Identify relevant competences and qualifications needed for pursuing further studies (career goals).	S6_9.1 Search for the necessary information and support for pursuing further studies (career).	C6_9.1 Manage learning tasks independently and take responsibility for own learning.
Subset 2 L6_9.2 **Personal capacities and attitudes**	K6_9.2 Identify own strengths and weaknesses, knowledge, skills, and attitudes and their impact on further studies.	S6_9.2 Reflect on own approach to learning, performing tasks and assignments and how to improve.	C6_9.2 Identify gaps in personal knowledge, skills and competences and undertake appropriate actions to improve personal competences.

3.5 Tuning-CALOHEE Assessment Reference Framework for Physics – LEVEL 7 EQF

Dimension 1: Theories and models			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_1. Level descriptor Theories and models	**K7_1** **Describe the concepts, laws, models, theories and limitations of classical physics and those of at least one of the specialised cores of modern physics, as well as their application across a wide range of real-life situations and different disciplines.**	**S7_1** **Use concepts, laws and theories from different domains of physics to model, analyse and explain a wide range of physical phenomena and observations.**	**C7_1** **Identify relevant theories and models required to interpret phenomena, observations, and real-life situations, also in the context of a different discipline, integrating concepts from different domains of classical and modern physics and recognising the limitations of the different theories and models.**
Subset 1 L7_1.1 **Theories and phenomena**	K7_1.1 Name, describe and explain the laws, theories, phenomena and limitations in the different domains of classical physics and at least one of the specialised cores of modern physics.	S7_1.1 Use physics theories and models from different domains of classical and modern physics to describe a complex physical system, to explain observations and make predictions.	C7_1.1 Identify relevant physics theories and models that are required to understand a phenomenon or observation, integrating concepts from different domains of physics and recognising the limitations of the different theories and models.
Subset 2 L7_1.2 **Applications of theories and models**	K7_1.2 Describe and explain how classical and modern physics are used across different real-life applications, also in the context of a different discipline.	S7_1.2 Apply elements of classical and/or modern physics to explain different real-life applications, also in the context of a different discipline.	C7_1.2 Identify which models and theories of classical and modern physics are relevant in different real-life problems, also in the context of a different discipline.

Dimension 2: Mathematical methods			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_2. Level descriptor Mathematical methods	**K7_2** **Name and describe standard and advanced mathematical (analytical and numerical) tools and methods and their application in the context of physics theories.**	**S7_2** **Apply standard and advanced mathematical (analytical and numerical) tools and methods to solve problems in physics.**	**C7_2** **Identify, adapt, integrate and employ both standard and advanced mathematical (analytical and numerical) tools and methods to solve problems and model situations in a variety of contexts.**
Subset 1 L7_2.1 **Mathematical tools**	K7_2.1 Name and describe standard and advanced mathematical tools and their application in the context of physics theories.	S7_2.1 Apply standard and advanced mathematical tools to model and solve complex problems in physics and to model physical phenomena.	C7_2.1 Identify, interpret, employ and justify the choice of the appropriate mathematical tool(s) to model, represent, and/or solve a problem in a wide range of situations, including real-life contexts.
Subset 2 L7_2.2 **Computational tools**	K6_2.2 Name and describe a wide range of computational tools and methods used in physics and the advanced features of at least one programming language.	S7_2.2 Use advanced computational tools (software, programming language) and methods to model and solve problems in physics.	C7_2.2 Evaluate and employ advanced computational tools and methods to model, represent, and/or solve a problem in a wide range of situations, including real-life contexts.

Dimension 3: Experimental design and scientific investigation			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_3. Level descriptor Experimental design and scientific investigation	**K7_3** **Describe standard and advanced experimental methods, instrumentation, techniques, theories and regulations used in experimental physics.**	**S7_3** **Design a complete physics experiment, using standard and advanced instrumentation safely and applying a wide range of methods, techniques and theories for data collection, analysis and reporting.**	**C7_3** **Set up and carry out scientific investigations independently and safely.**
Subset 1 L7_3.1 Experimental design and methodology	K7_3.1 Name and describe basic and advanced aspects of a scientific investigation as well as the physical quantities involved in a situation, and describe the inherent physical models or theories.	S7_3.1 Formulate predictions from hypotheses and devise an experimental plan to test them, also using modelling tools to design/model the experiment when necessary, and estimate the nature and order of magnitude of the results of an experiment.	C7_3.1 Conduct investigations independently, identifying the relevant theoretical framework and the process(es) required to obtain consistent results.
Subset 1 L7_3.2 **Instrumentation**	K7_3.2 Name and describe standard and some examples of advanced instrumentation, its characteristics and specifications.	S7_3.2 Set up different experimental arrangements, including some examples of non-standard/complex ones; identify the specifications of advanced instrumentation, use it and apply complex experimental procedures to gather data.	C7_3.2 Identify, arrange and employ advanced instrumentation to carry out an investigation, also in some complex situations and evaluate the correctness and significance of the measurement process and of the obtained data.
Subset 2 L7_3.3 **Data analysis**	K7_3.3 Name and describe basic and advanced methods and techniques for the processing of experimental data.	S7_3.3 Organise and analyse experimental data (including big data) using a variety of tools and techniques including basic and advanced software, identify sources of uncertainty and correctly apply them to the measurements, critically evaluate the reliability of experimental results and relate them to the initial hypotheses.	C7_3.3 Process complex sets of experimental data, evaluate the reliability of the results, draw sensible conclusions and use them to reformulate the hypotheses if necessary.
Subset 4 L7_3.4 **Experiment documentation**	K7_3.4 Describe a wide range of methods for recording the details of an experimental activity, storing and representing data (tables, different kinds of graphs, words, equations).	S7_3.4 Keep a record of the details and steps of an experiment, including the acquisition of data, also in complex experimental situations; use different representations to display data and results and write a complete and accurate laboratory report.	C7_3.4 Identify the appropriate method(s) to report on an investigation, communicate the results and debate on its outcomes.
Subset 5 L7 _3.5 **Safety**	K7_3.5 Describe the safety issues, equipment, procedures, behaviour, persons-in-charge and regulations of a specialised physics/science laboratory.	S7_3.5 Follow the safety regulations and procedures of a specialised physics/science laboratory, including using specialised protection equipment.	C7_3.5 Evaluate risk factors in an experimental environment, gather information about safety regulations in a working environment and

			operate accordingly, including the choice and use of appropriate protection equipment.

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Dimension 4: Problem solving			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_4. Level descriptor Problem solving	**K7_4** **Link concepts and laws from various domains of physics with advanced strategies, procedures, tools and criteria for framing, representing, solving and validating the results of a problem.**	**S7_4** **Categorise problems based on physical principles, including complex problems, context-rich problems, and problems derived from unfamiliar contexts; analyse a complex problem, recognise its structure and devise a creative plan for its solution, execute the devised plan and check for its validity.**	**C7_4** **Address complex problems and situations from the point of view of physics, identifying the laws and concepts that apply even in unfamiliar situations, devise and carry out a creative plan for reaching a solution and check its validity.**
Subset 1 L7_4.1 **Problem framing**	K7_4.1 Organise knowledge of physics principles and theories from different domains of physics in an articulated scheme that includes procedures and conditions for their application.	S7_4.1 Categorise problems and situations based on physics principles, including complex problems, context-rich problems, and problems derived from unfamiliar contexts; apply different procedures and schemata to frame a problem.	C7_4.1 Identify the deep structure of a complex and/or unfamiliar problem or situation, put it in a physical framework, identify common structures in problems drawn from different contexts, and generalise key features, approaches and solution methods.
Subset 2 L7_4.2 **Analytical thinking**	K7_4.2 Recall physics concepts and laws from different domains of physics relevant for a problem as well as advanced tools and strategies for representing a problem in terms of these concepts.	S7_4.2 Perform a complete analysis of a complex problem, break it down into smaller problems or tasks, extract relevant data and unknowns, represent a complex problem in a convenient way including modelling it with physical concepts, principles and equations, and devise a plan for its solution.	C7_4.2 Address problem situations analytically, recognising the phases or work packages of a problem and logically connecting them, and identify the best way of modelling a problem as well as the best strategy to tackle it.
Subset 3 L7_4.3 **Solution procedure and execution**	K7_4.3 Recall mathematical, (analytical and numerical) and/or technological tools relevant for the problem as well as the rules and procedures to use them.	S7_4.3 Execute the devised plan and flexibly and jointly apply different mathematical, numerical and/or technological tools to reach the solution of the problem, writing own code if necessary.	C7_4.3 Carry out a complex plan, which includes integration of different tools and phases, demonstrating perseverance and resilience in challenging situations.
Subset 4 L6_2.4 **Validation of results**	K6_4.4 Recall some standard criteria for stating the validity of a result.	S6_4.4 Apply standard criteria to check the validity of the solution and/or intermediate outcomes, e.g. evaluating the expected order of magnitude and units.	C6_4.4 Evaluate a process and its results, admitting the possibility of mistakes.

Subset 5 L6_4.5 **Creative and innovative thinking**	K6_4.5 Organise knowledge of physics in a way that facilitates links between different concepts and ideas.	S6_4.5 Reflect on own solution to a problem and compare it with others' solutions; acknowledge alternative ways to look at a same problem.	S6_4.5 Devise creative ways to address a problem, issue or task, and to exit critical issues or stuck situations.

Dimension 5: Scientific culture			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_5. Level descriptor Scientific culture	**K7_5** **Recall focused historical and epistemological facts on the conceptual development of physics theories and relate them to changes and/or issues in technology, society, and the rules of the scientific community.**	**S7_5** **Select and use different sources of information on the history, epistemology and current development of physics, and analyse different examples also in relation to technological and societal issues.**	**C7_5** **Identify common ideas and approaches in different areas of science, also in relation to its historical and epistemological evolution, and address scientific, technological and societal issues with an informed scientific, historical and epistemological approach.**
Subset 1 L7_5.1 **History of physics**	K7_5.1 Reconstruct the historical evolution of physics, also in relation to technological and societal changes.	S7_5.1 Select independently and use different sources of information on the history of physics, and analyse different examples and case studies also in relation to technological and societal issues.	C7_5.1 Identify common ideas and approaches in different areas of physics with reference to its history and debate on the influence of physics on technology and society in the present and in the past.
Subset 2 L7_5.2 **Epistemology**	K7_5.2 Describe different epistemological schemes that have influenced the development of physics theories and scientific theories in general.	S7_5.2 Utilise the epistemological schemes shared by the scientific community to address problems and issues in science and to assess the rigorousness of a scientific approach.	C7_5.2 Adopt an epistemological perspective in addressing scientific, technological and societal issues.
Subset 3 L7_5.3 **Sources of scientific information**	K7_5.3 Describe the procedures used by the scientific community to validate scientific works and describe the criteria for selecting reliable scientific information from libraries, databases, the Internet as well as any other source.	S7_5.3 Independently search for, evaluate, review, and use scientific information from a variety of sources, duly cite it when necessary, and assess the scientific value of a piece of information.	C7_5.3 Identify and manage relevant and reliable sources of information concerning scientific issues, and debate on them.

Dimension 6: Work ethic and integrity			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_6. Level descriptor Work ethic and integrity	**K7_6** **State general and specific ethical principles, norms, values, and standards relevant to the work of a physicist, and illustrate different examples when physics influences health, environment, politics and/or society.**	**S7_6** **Apply agreed ethical rules and rules of scientific conduct to behaviour in the profession.**	**C7_6** **Make decisions in line with ethical norms also in research environments and take responsibility for them, and actively contribute to local, national and international communities and (political) organisations according to own competence.**
Subset 1 L7_6.1 **Ethical rules in the profession**	K7_6.1 Recall general and profession-specific ethical principles, norms, values and standards.	S7_6.1 Apply principles, norms, values and standards to behaviour in the profession, both from a personal and a professional standpoint.	C7_6.1 Actively contribute to upholding, promoting and defending general and profession-specific specific ethical principles, norms, values and standards.
Subset 2 L7_6.2 **Awareness of professional actions impact**	K7_6.2 Illustrate different situations when your actions as a physicist affect health, environment and/or society.	S7_6.2 Acknowledge the consequences of own actions and estimate the impact of both established and new technological applications of physics on individuals, environment and society.	C7_6.2 Take responsibility for own professional actions and make decisions in line with the ethical norms and societal implications.
Subset 3 L7_6.3 **Governance and decision making**	K7_6.3 Illustrate different examples when physics theories and results affect (political) decisions and policymaking.	S7_6.3 Conduct informed processes of decision making in the profession.	C7_6.3 Actively contribute to and with local, national and international communities and (political) organisations.

Dimension 7: Communication			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_7. Level descriptor Communication	**K7_7** **Describe the different channels and tools of communication and their limitations.**	**S7_7** **Communicate effectively to present complex information in a concise manner orally and in writing and using ICT and technical language appropriate for the audience.**	**C7_7** **Evaluate scientific material and communicate it to a variety of audiences to inform, influence and debate using various techniques and technical language appropriate for the audience.**
Subset 1 L7_7.1 **Information sources**	K7_7.1 Describe the process by which information is communicated and the purposes of that communication.	S7_7.1 Critically evaluate the use and misuse of evidence, data, expert opinion in various media.	C7_7.1 Actively contribute to societal debates using reliable data and information based on reliable sources and informed judgements.
Subset 2 L7_7.2 **Data representation**	K7_7.2 Describe different representations of data (words, graphs, tables, animations).	S7_7.2 Use different representations of data.	C7_7.2 Compare and appraise the appropriate representation of data and construct a logical argument or presentation based upon it.
Subset 3 L7_7.3 **Means of communication**	K7_7.3 Identify and describe the role of different means of communication (scientific magazines, books, newspapers, video, web, etc.).	S7_7.3 Distinguish among different communication channels, produce simple scientific reports and oral presentations, using technical language appropriate for the audience.	C7_7.3 Identify and use the appropriate level, writing or oral style according to the context and communicative goals (laboratory report, dissertation, popular article, ...), using reliable sources.
Subset 4 L7 _7.4 **Technical English**	K7_7.4 Use the English language at the level necessary for physics communication.	S7_7.4 Read, speak, write and participate in discussions fluently in technical English.	C7_7.4 Study and communicate specific physics topics in technical English (minimum B2 level of Common European Framework of Reference for Languages), differentiating the language according to the audience and purpose of the communication.

Dimension 8: Project Management and Teamwork			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_8. Level descriptor Project Management and Teamwork	**K7_8** **Describe different project management tools.**	**S7_8** **Engage productively in an individual or group project.**	**C7_8** **Identify and implement an appropriate strategy to carry out an articulated individual or group project, collaborate constructively, perform leading and/or supervisory functions when needed, and take responsibility for the assigned tasks.**
Subset 1 L7_8.1 **Project management tools**	K7_8.1 Describe different project management tools for planning, organising, checking progress, and evaluating the results of a project.	S7_8.1 Use appropriate project management tools, set targets and priorities, evaluate project outcomes, and organise work to meet deadlines.	C7_8.1 Take responsibility for managing individual or group projects working independently.
Subset 2 L7_8.2 **Teamwork**	K7_8.2 Frame own and others' personal competences, viewpoints and strengths/weaknesses with respect to teamwork.	S7_8.2 Listen, share opinions and respectfully participate in conversation and/or discussion activities, use (receive and give) feedback, and take direction when appropriate.	C7_8.2 Identify own and others' competences, roles, strengths and weaknesses with respect to teamwork, contribute constructively and respectfully in a structured team across disciplines, and take responsibility for own task(s), including leading.
Subset 3 L7_8.3 **Organisations, societies and cultures**	K7_8.3 Recognise differences among individuals, organisations, societies and (work) cultures.	S7_8.3 Analyse and address issues and/or potential conflicts in and between individuals, organisations, societies and (work) cultures.	C7_8.3 Operate in a diverse group, organisation, society and/or (work) culture, identify appropriate interventions in the case of tensions or conflicts and actively engage to solve them.

Dimension 9: Professional development			
	Knowledge	*Skills*	*Autonomy and Responsibility*
L7_9. Level descriptor Professional development	**K7_9** **Identify relevant competences needed for continuing academic/professional development, as well as personal strengths, weaknesses and attitudes.**	**S7_9** **Organise own study and/or learning process, using different kinds of learning materials; link personal strengths and weaknesses to learning goals and search for learning/career development opportunities.**	**C7_9** **Enter new fields/environments of study or work through a positive attitude, evaluate own personal and professional competences and take responsibility for continuing academic/professional development, also in unfamiliar contexts.**
Subset 1 L7_9.1 **Professional requirements**	K7_9.1 Identify relevant competences and qualifications needed for continuing academic/professional development.	S7_9.1 Use different tools (ICT, literature search, etc.) for gaining new knowledge and skills, pursue further career, and gather information.	C7_9.1 Manage learning tasks independently, professionally and ethically, take responsibility for own academic/professional development also in unfamiliar learning contexts, acknowledge relevant issues and societal changes and take action to adapt to them.
Subset 2 L7_9.2 **Personal capacities and attitudes**	K7_9.2 Identify own strengths and weaknesses, knowledge, skills, and attitudes and their impact on further career.	S7_9.2 Reflect on own knowledge, skills and attitudes, set appropriate learning goals and strategies and search for the necessary learning/training opportunities.	C7_9.2 Identify gaps in personal knowledge, skills and competences and undertake appropriate actions to adapt to changes in the professional career.

4. Learning, teaching, and assessment

4.1. Introduction

In the Tuning methodology, the definition of clear learning outcomes is oriented to improve teaching, learning and assessment methods with a student-centred approach: 'With regard to teaching methodology, the key challenges are to: a) design and establish new learning environments where students can develop activities in order to encourage attitudes that are conducive to learning and contribute to competence development; b) apply continuous and periodic forms of assessment; and, c) use new information and communications technologies appropriately.' [4, p. 39].
In order to achieve these goals, different learning environments as well as teaching and assessment methods are possible, which may vary between institutions and will evolve with time due to advances in information technology and pedagogical theories. In many countries, the present phase of application and extension of the Bologna process provides a favourable context in which to test and implement innovation in curricular design and rethinking of specific course units. By matching learning, teaching and assessment approaches with specific learning outcomes we can create a powerful tool for change and positive innovation as well as elements on which quality can be built, monitored, evaluated and enhanced.

4.2. Matching teaching, learning and assessment methods with specific learning outcomes in the Physics Subject Area

In the process of identifying the dimensions and of the Assessment Framework presented in the previous chapter, the SAG also reflected on possible learning, teaching and assessment methods to achieve those goals. On a first run of reflection, we identified some general approaches and methods that could apply for each dimension. We report them briefly for 4 of the 9 dimensions in the table below, including two subject-specific competences (*Dimension 2: Mathematical methods* and *Dimension 3: Experimental design and scientific investigation*), one dimension pertaining the wider cultural aspect of Physics (*Dimension 5: Scientific culture*) and one dimension pertaining a generic competence (*Dimension 8: Project management and teamwork).*

	Learning	Teaching	Assessment
Dimension 2 **Mathematical methods**	• Compare different mathematical tools; • Practice using a computational tool/programming language to solve problems/model physical phenomena.	• Solve problems using the appropriate mathematical or computational tool and justify the choice; • Use computational tools/programming in a given context.	• Exercise-based homework; • Project-based tasks/lab reports; • Choice of proper computational tools/writing of code.
Dimension 3 **Experimental design and scientific investigation**	• Lab work in controlled environment; • Group work; • Individual work on specific sub-tasks; • Writing lab reports or presentations.	• Coaching; • Videos; • Interactive classroom demonstrations; • Visits to museums and research centres; • Seminars.	• Written report/presentation using rubrics; • Written or computer-based test; • Oral test/ presentation; • Tutor monitoring.

Dimension 5 **Scientific culture**	• Document (book, article) reading; • Lecture notes; • Group work; • Classroom discussion; • Literature search.	• Comment on scientific articles; • Seminars; • Videos/movies; • Visits to museums and research centres.	• Written essays; • Document analysis; • Oral/test/presentation/ discussion; • Group work.
Dimension 8 **Project management and teamwork**	• Analysis of projects; • Individual or group work on projects; • Peer-review activities; • Feedback activities (giving and receiving feedback).	• Prepare material on project management and group work; • Discuss project planning; • Provide examples of successful/unsuccessful projects; • Role play activities; • Discuss assessment rubrics.	• Rubric-based assessment of individual or group projects; • Peer-review with associated feedback; • Observation of group work.

However interesting this list could be for a general idea on possible learning, teaching and assessment methods, it does not clarify the match between learning, teaching and assessment methods with specific learning outcomes, which are the descriptors of each-sub-dimension structured in the three categories 'Knowledge', 'Skills', and 'Autonomy and Responsibility'; moreover, they do not specify the progression between the first and second cycle. We chose to analyse in detail one dimension (*Dimension 3: Experimental design and scientific investigation*). This dimension is highly representative of the physics subject area and has been the subject of a great deal of literature in Physics Education Research. A relevant example that inspired the reflection of the SAG is that of Etkina et al. [12], which integrates the concepts of interpretive knowing (developing a "scientific" way of looking at conceptual and experimental problems), cognitive apprenticeship (an approach where learning is supported by means of modelling, coaching, and scaffolding) and formative assessment. A complete analysis of the dimension in terms of learning, teaching and assessment methods for the two levels is reported in the following pages.

LEARNING, TEACHING AND ASSESSMENT METHODS FOR DIMENSION 3 - LEVEL 6 EQF

Note: Rubric-based assessment with shared rubrics is assumed throughout the table.

Dimension 3: Experimental design and scientific investigation			
	Knowledge	*Skills*	*Autonomy and Responsibility*
Experimental design and scientific investigation	**Describe standard methods, instrumentation, techniques, theories and regulations used in experimental physics.**	**Design a simple experimental investigation, using standard instrumentation and follow guidelines, and apply basic methods, techniques and theories for data collection, analysis and reporting.**	**Set up and carry out simple scientific investigations safely under supervision.**
Experimental design and methodology	Name and describe the basic aspects of a scientific investigation as well as the physical quantities involved in a situation, and describe the inherent physical models or theories.	Formulate a simple prediction from a hypothesis and devise a plan to test it, and estimate the order of magnitude of the results of an experiment.	Conduct simple investigations under supervision, identifying the relevant theoretical framework and the process required to obtain consistent results.
Learning	Observation of experiments and guided reflection with peers. Historical and literature readings. Describe physical situations using multiple representations.	Design a simple testing experiment for a known equation, working in small groups. Receive/give feedback.	Conduct simple application experiments where students are given some responsibility about the choice of variables. Guided meta-cognitive reflection (purpose of the experiment, criteria for judging the agreement between prediction and outcomes).
Teaching	Presentation of case studies and classroom demonstrations. Problem-solving recitations. Provide literature/historical readings. Prompt reflection on the links between theory and experiments, and between classroom demonstration and lab practice.	Prepare handouts with scaffolding questions to help students identify the hypothesis, prediction and expected outcomes and devising a plan. Interact with groups by prompting reflection on key or critical aspects. Provide feedback.	Prepare handouts with scaffolding questions/hints to help students design the experiment Provide students with relevant references (software, study material). Set up an online learning environment to promote peer/instructor discussion.
Assessment	Require reference to relevant physical models in the lab report. Verify the correct reference to elements of the investigation (hypothesis, prediction, outcomes, etc.).	Short group report containing hypotheses, predictions, and plans. Group observation and interactions during the lab sessions. Self- and peer-assessment opportunities.	Group report complemented by individual reflection describing and justifying hypotheses, predictions, expected outcomes, choices, and reference to theoretical frameworks.

Instrumentation	Name and describe standard instrumentation used in experimental physics and their specifications.	Set up standard experimental arrangements, identify the specifications of standard instrumentation, use it under supervision and apply simple experimental procedures to gather data.	Identify, arrange and employ the appropriate instrumentation to carry out an investigation, under supervision and/or in standard situations.
Learning	Observation of classroom demonstrations focused on instrumentation. Historical readings. Visits to museums and laboratories.	Set up a simple experiment with given equipment and write down the specifications, working in small groups. Receive/give feedback.	Choose between different possible instrumentation and procedures and discuss the choice with peers/instructor.
Teaching	Presentation of case studies and classroom demonstrations focussed on instrumentation. Use of informal environments (museums, laboratories).	Demonstrate use of equipment and assist students in its use. Formulate questions to help them reflect on the purpose of given equipment. Provide feedback.	Prepare handouts with guiding questions to help students identify the correct setup. Discuss students' choice.
Assessment	Require setup description and reference to used instrumentation and its specifications in the lab report.	Require a description of the data collection procedure used in the experiment in the report and verify its consistence. Group observation and interactions during the lab sessions.	Evaluate the consistence and appropriateness of the chosen instrumentation/procedures as described in a group report and require individual reflections/justification.
Data analysis	Name and describe basic methods and standard techniques for the processing of experimental data.	Organise and analyse experimental data using standard tools and techniques, including basic software; estimate and correctly apply uncertainties and evaluate the reliability of results.	Process simple sets of experimental data and evaluate the reliability of results.
Learning	Observation of classroom demonstrations focussed on data processing techniques. Study of literature and handouts.	Collect and analyse data of from a variety of given sources and evaluate uncertainties, working in small groups. Receive/give feedback.	Compare data obtained by different methods also in terms of handling of uncertainties Guided meta-cognitive reflection (e.g. judging the agreement between prediction and outcomes)
Teaching	Presentation of case studies and classroom demonstrations focussed on data processing techniques. Provide handouts/reference materials.	Set up different experimental situations to help students appreciate the differences between methods/procedures. Provide examples and exercises. Prompt reflection on key or critical aspects. Provide feedback.	Prepare worksheets with guiding questions to help students compare data obtained by different procedures/methods. Provide questions for meta-cognitive reflection.
Assessment	Require reference and justification of the chosen data processing techniques in the report.	Require justification of calculated uncertainties and reflection on the significance of results in the lab report.	Require a critical discussion about the quality and significance of data and results, together with possible explanations of unexpected results, in a group report with individual reflections.

		Discuss the reliability of results individually in an oral exam.	
Experiment documentation	Describe standard methods of recording the details of an experimental activity and storing data.	Keep a record of the details and steps of an experiment, including the acquisition of data, and write a simple laboratory report.	Identify the appropriate method to report on an investigation and communicate the results.
Learning	Literature/historical readings. Discussion with peers.	Regular use of a lab notebook. Hand in a draft report and receive feedback Self-assessment (e.g. by comparison with exemplars or peers).	Study of 'exemplars' (e.g. well-written vs badly-written lab report). Guided meta-cognitive reflection (e.g. on the purpose of a lab and efficacy for learning).
Teaching	Illustrate the purpose and use of a lab notebook. Classroom discussion on report writing. Provide literature/historical readings.	Provide scaffolded worksheets to help students frame their report (but avoid structuring the report for them). Provide feedback on draft reports.	Provide and present 'exemplars' (e.g. well-written vs badly-written lab report). Provide questions for meta-cognitive reflection and organise follow-up activities aimed at reflecting on lab outcomes.
Assessment	Require the use of, and correct reference to different methods for documenting an experiment in the report.	Require the presence of all the relevant details and steps of an experiment in a group report. Require clearness and completeness of the documentation.	Require a presentation of an investigation in the form students prefer.
Safety	Describe the main safety issues, equipment and regulations of a standard physics laboratory.	Follow the safety regulations of a standard physics laboratory, including using basic individual protection equipment.	Identify the safety regulations of a physics laboratory and operate accordingly, including the use of appropriate protection equipment.
Learning	Review safety regulations of a laboratory and discuss them with peers/instructor.	Regular use of different kinds of protection equipment.	Reflect with peers/instructor about possible safety regulations each time a new laboratory environment/setup is introduced.
Teaching	Provide and discuss safety regulations Illustrate the use and location of safety instructions.	Display use of protection equipment Provide opportunities to use different equipment and apply different regulations Give feedback and advice.	Encourage students to reflect about safety regulations each time a new laboratory environment/setup is introduced.

Assessment	Require reference to safety regulations in the reports when relevant.	Observation of individual and group work.	Discuss the meaning and implication of safety regulations either orally or in the reports.

LEARNING, TEACHING AND ASSESSMENT METHODS FOR DIMENSION 3 - LEVEL 7 EQF

Note: Rubric-based assessment with shared rubrics is assumed throughout the table.

Dimension 3: Experimental design and scientific investigation			
	Knowledge	*Skills*	*Autonomy and Responsibility*
Experimental design and scientific investigation	**Describe standard and advanced experimental methods, instrumentation, techniques, theories and regulations used in experimental physics.**	**Design a complete physics experiment, using standard and advanced instrumentation safely and applying a wide range of methods, techniques and theories for data collection, analysis and reporting.**	**Set up and carry out scientific investigations independently and safely.**
Experimental design and methodology	Name and describe basic and advanced aspects of a scientific investigation as well as the physical quantities involved in a situation, and describe the inherent physical models or theories.	Formulate predictions from hypotheses and devise an experimental plan to test them, also using modelling tools to design/model the experiment when necessary, and estimate the nature and order of magnitude of the results of an experiment.	Conduct investigations independently, identifying the relevant theoretical framework and the process(es) required to obtain consistent results.
Learning	Historical and literature readings, including recent literature, and discussion with peers.	Design a complex testing experiment for a known physics equation/model, working in small groups. Practice using different modelling tools and software. Receive/give feedback	Engage with complex, open-ended experiments whose goals are drawn from recent scientific literature (e.g. reproduce research results or test them in a new context). Students are free to choose the timing, materials, procedures, setup, analysis methods and priorities.
Teaching	Presentation of case studies and classroom demonstrations. Provide literature/historical readings, highlighting the links between theory and experiment, and prompt reflection.	Provide minimally scaffolded materials and encourage interactions within/between groups. Provide relevant literature/references and comment on them. Prompt reflection on the links between theory and experiment, also highlighting the role of simulations and comparing independent methods to test a theory. Provide feedback.	Provide students with relevant literature. Encourage peer interaction and comparison of different strategies. Highlight critical points and provide feedback.
Assessment	Require reference to relevant physical models in the lab report.	Articulated group report containing hypotheses, predictions, and plans. Group observation and interactions during the lab sessions.	Group/individual report describing and justifying hypotheses, predictions, expected outcomes, choices, reference to theoretical frameworks and to literature.

Instrumentation	Name and describe standard and some examples of advanced instrumentation, its characteristics and specifications.	Set up different experimental arrangements, including some examples of non-standard/complex ones; identify the specifications of advanced instrumentation, use it and apply complex experimental procedures to gather data.	Identify, arrange and employ advanced instrumentation to carry out an investigation, also in some complex situations and evaluate the correctness and significance of the measurement process and of the obtained data.
Learning	Observation of classroom demonstrations focussed on advanced instrumentation. Historical readings. Visits to museums and research centres	Set up complex experiments with given equipment and discuss the chosen arrangement with peers. Receive/give feedback.	Choose the instrumentation and process for a self-designed experiment based on literature and discussion with peers/instructor/technician.
Teaching	Presentation of case studies and classroom demonstrations focussed on advanced instrumentation. Use of informal environments (museums, laboratories, research centres).	Demonstrate use of non-standard equipment. Formulate questions to help students reflect on the relationship between equipment and experiment. Provide feedback.	Provide relevant literature/references and comment on them. Provide feedback.
Assessment	Require setup description and reference to used instrumentation, including advanced one, and its specifications in the lab report.	Require a description of the data collection procedure used in the experiment in the report and verify its consistence. Group observation and interactions during the lab sessions.	Evaluate the consistence and appropriateness of the chosen instrumentation/procedures in an individual report or a group report with individual reflections.
Data analysis	Name and describe basic and advanced methods and techniques for the processing of experimental data.	Organise and analyse experimental data (including big data) using a variety of tools and techniques including basic and advanced software, identify sources of uncertainty and correctly apply them to the measurements, critically evaluate the reliability of experimental results and relate them to the initial hypotheses.	Process complex sets of experimental data, evaluate the reliability of the results, draw sensible conclusions and use them to reformulate the hypotheses if necessary.
Learning	Observation of classroom demonstrations focussed on advanced data processing techniques. Study of recent literature Peer discussion	Collect and analyse data of from a variety of given sources (including big data), working in small groups. Compare the outcomes with simulations. Meta-cognitive reflection on the relationship between hypotheses, predictions and outcomes. Receive/give feedback.	Choose priorities and procedure for a self-designed experiment upon literature reading and discussion. Compare the outcomes with simulations. Guided meta-cognitive reflection (e.g. judging the agreement between prediction and outcomes).

Teaching	Presentation of case studies and classroom demonstrations focussed on advanced data processing techniques.	Set up a variety of experimental situations providing minimally scaffolded materials about data analysis, but interact constantly with groups during the experiments to prompt reflection on key or critical aspects. Provide feedback.	Provide relevant literature/references and comment on them. Encourage students to compare their work with literature. Provide questions for meta-cognitive reflection.
Assessment	Require reference and justification of the chosen data processing techniques in the report.	Require reflection on the reliability and significance of results in the lab report and individually in an oral exam.	Require a critical discussion about the quality and significance of data and results, together with possible explanations of unexpected results, and a comparison with literature if applicable.
Experiment documentation	Describe a wide range of methods for recording the details of an experimental activity, storing and representing data (tables, different kinds of graphs, words, equations).	Keep a record of the details and steps of an experiment, including the acquisition of data, also in complex experimental situations; use different representations to display data and results and write a complete and accurate laboratory report.	Identify the appropriate method(s) to report on an investigation, communicate the results and debate on its outcomes.
Learning	Advanced literature and historical readings, including recent ones and those using non-standard methods. Discussion with peers.	Hand in a draft report and receive instructor/peer feedback; Self-assessment (e.g. by comparison with exemplars or peers).	Guided meta-cognitive reflection (e.g. on the purpose of a lab and its relevance for current physics knowledge) Peer discussion/group work.
Teaching	Provide literature/historical readings. Demonstrate how to refer to relevant literature and sources.	Provide feedback on draft reports. Classroom demonstrations on how to use different representations to display data.	Provide questions for meta-cognitive reflection. Provide opportunities to communicate the results to others.
Assessment	Require fluent use of different methods for documenting an experiment.	Require a reasonable and correct logical structuring in complex reports and verify the presence of all the steps and relevant details. Require accuracy s and completeness of the documentation. Require different forms of presentation, e.g. seminar or talk besides the written report.	Require a presentation of an investigation in the form students prefer, followed by a debate.
Safety	Describe the safety issues, equipment, procedures, behaviour, persons-in-charge and regulations of a specialised physics/science laboratory.	Follow the safety regulations and procedures of a specialised physics/science laboratory, including using specialised protection equipment.	Evaluate risk factors in an experimental environment, gather information about safety regulations in a working environment and operate accordingly, including the choice and use of appropriate protection equipment.

Learning	Make individual experience of a specialised laboratory and interact with persons-in-charge. Follow specific safety courses.	Regular use of protection equipment, including specialised one	Reflect with peers/instructor about risk factors each time a new working environment/setup is introduced, including the use of appropriate protection equipment
Teaching	Provide specific instructions, also with the help of a specialised technician. Discuss specific regulations.	Display use of both standard and specialised protection equipment. Give feedback and advice.	Promote reflection about safety regulations each time a new working environment is introduced.
Assessment	Require a reference to safety in the report. Require a specific exam on safety.	Observation of individual/group work.	Discuss the meaning and implication of safety regulations either orally or in the reports.

4.3. Good practices across Europe

A survey on the teaching, learning and assessment strategies adopted in European universities in their physics degree programmes was conducted during the CALOHEE project. The investigation involved 15 universities, representative of the following countries: ES, FI, FR, HU, IE, IT, NL, PL, PT, TR, UK. The outcomes of this survey suggest that most European institutions follow in general a traditional way of learning and teaching, as well as of assessment. However, this does not mean that all physics degree courses in European universities are using traditional methods only. A recent survey conducted in the framework of the HOPE European Project reported several examples of good practices in physics teaching across Europe [13].

The Technische Universiteit Eindhoven reports an innovative educational method based on interactive teaching with clickers, online assignments and web-based lectures [14]. It was introduced to create interaction and motivation, improve students' results, and encourage formative assessment strategies. The method, named *Studio Classroom*, was first applied to teach Quantum Physics, a second-year bachelor course. Studio Classroom is a combination of interactive lectures, tutorials and self-study in unit blocks, carried out within small groups. Individual formative feedback by clickers was introduced as a rapid assessment tool to provide an overview on progress and identify gaps by means of questioning students at three levels: conceptual, prior knowledge, and homework exercises. The format has been developed as a result of several adjustments and improvements, evolving from a traditional course.

Another interesting example was developed by the University of Ljubljana for first-year students [15]. It consists in the modification of an existing experimental subject into a 'project laboratory' for first-year physics students. Project laboratories are usually developed as opposed to more traditional 'close-ended' laboratories where student have limited freedom to choose the goals, methods, constraints, and the sequence of their experimental activity. In the project laboratory developed at the University of Ljubljana, students are given a well-defined, sufficiently simple and attractive project task but little or no initial hints for the solution; instead, they are given time for preparation and brain storming, role assignment within the group, consideration of the constraints of the project (time, manpower, equipment, etc.), and literature search. Coaching is achieved by giving hints when students get lost and advice when they get too ambitious, as well as providing access and input to literature. At the end of the projects, students are required to write a final report in the form of an online page and give/receive feedback. Remarkably, the proposed projects were inspired by Physics Education Research (PER) in the form of articles from journals such as the European Journal of Physics, the American Journal of Physics, Physics Education and The Physics Teacher. The goal of this project was to develop both subject-specific and general competences jointly. Reported generic competences (together with a rough comparison with the Dimensions of the CALOHEE-Physics framework) were: Problem solving and creative thinking (included in *Dimension 4*: Problem solving of the CALOHEE-Physics framework); Capacity to learn (*Dimension 9: Professional development*); Time management, organisation and planning, teamwork, leadership and interpersonal skills (*Dimension 8: Project management and teamwork*), Specific communicational skills (*Dimension 7: Communication*).

9. Final remarks

Since the global context is rapidly evolving, universities have to face new challenges. This document offers a stimulus for those involved in the innovation of teaching, learning and assessment practices, and draws on the exchange of ideas and experiences among different countries.

It is now widely accepted that structuring a degree profile through learning outcomes can help determine whether the intended level of learning has actually been achieved, in order to provide transparency, objectivity and fairness for all the stakeholders. Moreover, given the role of HE institutions to prepare students for facing the needs of today's society and to settle strong bases for their personal and professional development, it is important to take into account both subject-specific and generic competences. This seems to be even more necessary and urgent when we acknowledge recent global events (e.g. refugee crises, the lasting effects of the 2008 financial crisis, xenophobia, populism, etc.). We believe that re-thinking teaching and learning approaches in the light of promoting civic, social and cultural engagement is necessary.

These learning outcomes should be identifiable, assessable and recognised by those who are designing degree programmes. This is why those building up the *Tuning Subject Area Qualifications Reference Framework* (Meta-Framework) and the more detailed *Tuning-CALOHEE Assessment Reference Framework for Physics* were developed by a panel of experts in Physics. Remarkably, a common core has been found despite national differences in approach, traditions, and policies, upon which the Assessment Reference Framework was built. We believe that this is a good starting point for collaboration at the supranational level. This collaboration is now necessary, since the higher education sector has achieved a strongly international character and students need and want to be mobile across Europe. This is particularly true for the Physics Subject Area.

Another distinctive feature of this document is the importance given to the relationship between learning outcomes and teaching, learning and assessment methods. We are witnessing a worldwide reflection on teaching, learning and assessing method and, in general, a shared drive to innovation in this regard. Student-centred approaches, common to the Tuning methodology, are recognised by current pedagogical models as the key to innovate learning, teaching and assessment and an increasing number of institutions are working to transform their courses in this way. This is also the case for Physics, where Physics Education Research has been working for many years on these topics and has provided consistent results that are now being implemented by HE institutions. We believe that effort presented in this document to accurately and punctually match learning outcomes with specific learning, teaching and assessment strategies inspired by research in Physics Education is a unique and powerful tool for those who are trying to innovate physics degree courses.

In conclusion, we hope that the present Reference *Frameworks* and *Guidelines* will serve as a reference for constructing new programmes and enhancing existing ones, and that it will be useful for learners and institutions in the Physics Subject Area.

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Glossary

See also **http://ec.europa.eu/education/ects/users-guide/glossary_en.html**

Assessment Reference Framework
A table containing the learning outcomes or descriptors defined as part of a Subject Area Qualifications Reference Framework of Meta-Profile and more precise subsets of each one of them. Each subset, taken together, describes in some detail the core elements and topics covered by a learning outcome statement. In addition, the Assessment Reference Framework intends to offer insight in the most appropriate strategies and approaches needed to assess the constituent elements of each learning outcome.

Competence
The European Qualifications Framework (EQF) defines a competence as 'the ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development'. In the context of the EQF, a competence is described in terms of responsibility and autonomy.
Fostering competences is the goal of all educational programmes. Competences are developed in all course units and assessed at different stages of a programme. Some competences are subject-specific (related to a specific field of study), others are generic (common to any degree course). It is normally the case that competence development proceeds in an integrated and cyclical manner throughout a programme.

Credit (ECTS)
ECTS credits express the volume of learning based on the defined learning outcomes and their associated workload. 60 ECTS credits are allocated to the learning outcomes and associated workload of a full-time academic year or its equivalent, which normally comprises a number of educational components to which credits (on the basis of the learning outcomes and workload) are allocated. ECTS credits are generally expressed in whole numbers.

Dublin Descriptors
The Dublin Descriptors are the cycle descriptors (or 'level descriptors') presented in 2003 and adopted in 2005 as the Qualifications Framework of the European Higher Education Area. They offer generic statements of typical expectations of achievements and abilities associated with awards that represent the end of each of a (Bologna) cycle or level. The descriptors are phrased in terms of competence levels, not learning outcomes, and they enable to distinguish between the different cycles in a broad and general manner. A level descriptor includes the following five components:

- knowledge and understanding;
- applying knowledge and understanding;
- making judgements;
- communication;
- lifelong learning skills.

Employability
Employability can be defined in short as 'the skills and abilities that allows someone to be employed'. The UK Higher Education Academy/ESECT have come up with the following definition of employability-

related competences: 'A set of skills, knowledge and personal attributes that make an individual more likely to secure and be successful in their chosen occupation(s) to the benefit of themselves, the workforce, the community and the economy.[2]'

European Credit Transfer and Accumulation System (ECTS)
A learner-centred system for credit accumulation and transfer, based on the principle of transparency of learning, teaching and assessment processes. Its objective is to facilitate planning, delivery and evaluation of study programmes and student mobility by recognising learning achievements and qualifications and periods of learning.

European Higher Education Area (EHEA)
The European Higher Education Area (EHEA) was launched on the Bologna Process decade anniversary in March 2010, during the Budapest-Vienna Ministerial Conference. Building on the main objectives of the Bologna Process since its inception in 1999, the EHEA is meant to ensure more comparable, compatible, coherent and attractive systems of higher education in Europe.

European Qualifications Framework for Lifelong Learning (EQF)
The European Qualifications Framework for Lifelong Learning is a common European reference framework which enables countries of the European Union to link their qualifications systems to one another. It was adopted by the European Parliament and Council in April 2008. The EQF uses eight reference levels based on learning outcomes that are defined in terms of knowledge, skills and competence. It shifts the focus from input (lengths of a learning experience, type of institution) to what a person holding a particular qualification actually knows and is able to do. It makes qualifications more readable and understandable across different countries and systems in the European Union.

Qualifications Framework of the European Higher Education Area (QF-EHEA)
In the European Higher Education Area, qualifications frameworks are found at two levels. An overarching framework (QF-EHEA) has been adopted in 2005 and all member countries committed themselves to develop national qualifications frameworks that are compatible with this overarching framework.
A national qualifications framework for higher education encompasses all the qualifications in a higher education system. It shows the expected learning outcomes for a given qualification and how learners can move between qualifications.
The aim of QF-EHEA is to organise national higher education qualifications into an overarching European-wide qualifications framework. Within this Framework, qualifications are defined according to levels of complexity and difficulty (Bachelor, Master, Doctor).
The QF-EHEA identifies four main cycles which are described by the 'Dublin Descriptors'. They offer generic statements of typical expectations of achievements and abilities associated with awards that represent the end of each of a cycle. The short, first and second cycles are also characterised by credit ranges.

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Knowledge
The body of facts, principles, theories and practices that is related to a field of work or study. In the context of the European Qualifications Framework, knowledge is described as theoretical and/or factual. For the bachelor and master level, knowledge is specified as follows:
Bachelor level: advanced knowledge of a field of work or study, involving a critical understanding of theories and principles.
Master level: highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research. Critical awareness of knowledge issues in a field and at the interface between different fields.

Learning outcome
A statement of what a learner knows, understands and is able to do on completion of a learning process. The achievement of learning outcomes has to be assessed through procedures based on clear and transparent criteria. Learning outcomes are attributed to individual educational components and to programmes at a whole. They are also used in European and national qualifications frameworks to describe the level of the individual qualification.

Lifelong learning
All learning activity undertaken throughout life, with the aim of improving knowledge, skills and competences within a personal, civic, social and/or employment-related perspective.
Programmes and services contributing to lifelong learning within the higher education sector may include mainstream programmes, continuing education, evening classes, specific programmes for part-time learners, access to libraries/higher education institution resources, distance learning, training courses, targeted guidance and counselling services among other actions and initiatives.

Skill
The ability to apply knowledge and use know-how to complete tasks and solve problems.
In the context of the European Qualifications Framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments). For the bachelor and master level, skills are specified as follows:
Bachelor level: advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study.
Master level: specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields.

Wider Competences
Operationalisation of knowledge and skills in the world of work: tasks/activities that the graduate is able to perform and responsibilities the he/she is able to take on in the workplace.
They reflect both the parameters 'Employability' and 'Civic, Social and Cultural Engagement'. Fostering competences is the object of a process of learning and of an educational programme. For the bachelor and master level, skills are specified as follows:
Bachelor level: manage complex technical or professional activities or projects, taking responsibility for decision making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups.

Master level: manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams.

Student-Centred Learning

A learning approach characterised by innovative methods of teaching which aim to promote learning in communication with teachers and students and which takes students as active participants in their own learning, fostering transferable skills such as problem-solving, critical and reflective thinking (ESU, 2010).

Annex 1. List of the first Subject Area Group for Physics 2001-2008 (Tuning Physics SAG)

The working group was co-ordinated by Luigi Filippo Donà dalle Rose and Hendrik Ferdinande, who edited the first edition of the brochure. All SAG members below have contributed to the 2009 edition Reference Points for the Design and Delivery of Degree Programmes in Physics.

Members of the 1st Physics Subject Area Group (SAG)	
Maria Ebel Technische Universität Wien Austria	**Hendrik Ferdinande** Universiteit Gent Belgium
Stig Steenstrup University of Copenhagen Denmark	**Jouni Niskanen** Helsingin Yliopisto Finland
Edouard Kierlik Université Pierre et Marie Curie, Paris VI France	**Peter U. Sauer** Universität Hannover Germany
Ev.G. Vitoratos Panepistimion Patron Greece	**Eamonn Cunningham** Dublin City University Ireland
Luigi F. Donà Dalle Rose Università di Padova Italy	**Francesca Matteucci** Università di Trieste Italy
Hay Geurts University of Nijmegen The Netherlands	**Maria Celeste Do Carmo** Universidade de Aveiro Portugal
Laura Tugulea University of Bucharest Romania	**Fernando Cornet** Universidad de Granada Spain
Göran Nyman Chalmers University of Technology Sweden	**Oleksandr Suk** National Technical University Kharkiv Polytechnic Institute Ukraine
W. Gareth Jones Imperial College London United Kingdom	

Annex 2 - CALOHEE Framework for Civic, Social and Cultural Engagement

	Knowledge	Skills	Autonomy and Responsibility (Wider competences)
1.	Demonstrate critical understanding of similarities and differences in and between *societies and cultures*	Identify, describe and analyse interaction in and between societies and cultures	Demonstrate engagement *in the public and professional domain* by developing scenarios and alternatives and/or identifying best practices of interaction between societies and cultures and – if required – interventions in case of tensions and/or conflicts
2.	Demonstrate critical understanding of the processes of *information and communication*	Review and judge (mis)use of sources, data, evidence, qualities, intentions and transparency and expert opinions	Active contribution *in the public and professional domain* to societal debates using reliable data and information sources and informed judgements
3.	Demonstrate critical understanding of the processes of *governance and decision making*	Apply and support agreed governing principles, norms and values regarding fairness, transparency, accountability, democracy and relevance in decision and policy making processes	Active contribution to and with local and (inter)national communities, community groups, (political) organisations and pressure groups respecting agreed principles, norms and values
4.	Demonstrate critical understanding of general ethical principles, norms and values and professional standards	Understand and apply the processes of decision making and the consequences of actions taking into account principles, norms, values and standards both from a personal and a professional standpoint.	Active contribution to upholding, promoting and defending general ethical principles, norms, values and professional standards in governance, communication and cultural interaction *in the public and professional domain.*

This table was prepared by (in alphabetical order): Pablo Beneitone, Julia González Ferreras, Alfredo Soeiro, Robert Wagenaar, Ingrid van der Meer and Maria Yarosh.

Contact

The Tuning Projects, including CALOHEE, are co-ordinated by the University of Deusto, Bilbao, Spain and the University of Groningen, The Netherlands.

General Co-ordinators

Robert Wagenaar Director International Tuning Academy University of Groningen r.wagenaar@rug.nl	Pablo Beneitone Director International Tuning Academy Deusto University, Bilbao pablo.beneitone@deusto.es

Contact

Ingrid van der Meer Project Manager International Tuning Academy Faculty of Arts University of Groningen P.O.Box 716 9700 AS Groningen The Netherlands Tel.: +31 50 363 6059 y.van.der.meer@rug.nl

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