



UNIVERSIDAD
POLITÉCNICA
DE MADRID

PROCESO DE
COORDINACIÓN DE LAS
ENSEÑANZAS PR/CL/001



E.T.S. de Ingenieros de
Telecomunicacion

ANX-PR/CL/001-01

GUÍA DE APRENDIZAJE

ASIGNATURA

93000923 - Temas Avanzados En Tecnología De Antenas

PLAN DE ESTUDIOS

09AT - Master Universitario En Teoria De La Señal Y Comunicaciones

CURSO ACADÉMICO Y SEMESTRE

2024/25 - Primer semestre

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1. Datos descriptivos

1.1. Datos de la asignatura

Nombre de la asignatura	93000923 - Temas Avanzados en Tecnología de Antenas
No de créditos	6 ECTS
Carácter	Optativa
Curso	Primer curso
Semestre	Primer semestre
Período de impartición	Septiembre-Enero
Idioma de impartición	Inglés/Castellano
Titulación	09AT - Master Universitario en Teoría de la Señal y Comunicaciones
Centro responsable de la titulación	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Curso académico	2024-25

2. Profesorado

2.1. Profesorado implicado en la docencia

Nombre	Despacho	Correo electrónico	Horario de tutorías *
Adrian Tamayo Dominguez (Coordinador/a)	C-418	a.tamayo@upm.es	Sin horario. Appointment arranged by email
Francisco Eduardo Carrasco Yepez	B-417	eduardo.carrasco@upm.es	Sin horario. Appointment arranged by email

Jose Manuel Fernandez Gonzalez	C-416	josemanuel.fernandez.gonzalez@upm.es	Sin horario. Appointment arranged by email
Jose Daniel Martinez De Rioja Del Nido	B-403	jd.martinezderioja@upm.es	Sin horario. Appointment arranged by email
Pablo Sanchez Olivares	C-416	pablo.sanchezo@upm.es	Sin horario. Appointment arranged by email
Jose Luis Masa Campos	C-419	joseluis.masa@upm.es	Sin horario. Appointment arranged by email

* Las horas de tutoría son orientativas y pueden sufrir modificaciones. Se deberá confirmar los horarios de tutorías con el profesorado.

3. Conocimientos previos recomendados

3.1. Asignaturas previas que se recomienda haber cursado

El plan de estudios Master Universitario en Teoría de la Señal y Comunicaciones no tiene definidas asignaturas previas recomendadas para esta asignatura.

3.2. Otros conocimientos previos recomendados para cursar la asignatura

- It is recommended to know Matlab programming
- It is recommended to have a strong knowledge in basic concept about antennas, radiated fields, electromagnetic waves and basic antenna parameters

4. Competencias y resultados de aprendizaje

4.1. Competencias

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB08 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo

CE01 - Analizar y aplicar técnicas para el diseño y desarrollo avanzado de equipos y sistemas, basándose en la teoría de la señal y las comunicaciones, en un entorno internacional

CE02 - Evaluar y sintetizar los resultados de un trabajo en equipo en proyectos relacionados con la teoría de la señal y las comunicaciones, en un entorno internacional.

CE03 - Valorar y contrastar la utilización de las diferentes técnicas disponibles para la resolución de problemas reales dentro del área de teoría de la señal y comunicaciones.

CT01 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa

CT03 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas

CT04 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo

CT05 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de

documentos técnicos y científicos, de una manera adecuada y eficiente

CT06 - Capacidad para emitir juicios sobre implicaciones económicas, administrativas, sociales, éticas y medioambientales ligadas a la aplicación de sus conocimientos

4.2. Resultados del aprendizaje

RA66 - Knowing antenna measurement systems and their limitations

RA25 - Handle with ease the bases of linear algebra and calculus necessary to formulate problems optimization.

RA24 - Knowledge of advanced techniques used in the Radio Access Technologies

RA9 - To evaluate and to implement RF systems and equipments.

RA28 - Know and evaluate the different types of antennas according to their specifications

RA23 - Knowing the antenna measurement systems and their limitations

RA27 - Ability to design antenna arrays (arrays)

RA30 - Ability antenna design for communications and radar systems

RA26 - Ability of oral and written communication

RA35 - Understanding the need of computational electromagnetics

5. Descripción de la asignatura y temario

5.1. Descripción de la asignatura

This course presents advanced concepts and techniques in antenna topics. The students will acquire the required knowledge for the analysis and design of antennas using in-house software and commercial software. These techniques cover either theoretical and practical design aspects. With this goal, the students obtain the knowledge needed to perform antenna analysis and design in the most recent antenna technology and using commercial and self-made software. The course learning method is based on the main parts of the antenna design topics based on student work and Project Based Learning methodology with the support of the professors.

All the course classes are referred to practical antenna systems. Several antenna design and optimization methods are presented in the classroom. The students will use the software packages at the Signals, Systems and

Radiocommunications Department of the E.T.S.I. Telecomunicación to perform practical analysis either by the professors and for practical students projects. The students will understand the concepts of the antenna analysis and design.

5.2. Temario de la asignatura

1. Printed antennas

- 1.1. Overview of printed antennas
- 1.2. Wideband and multiband antennas
- 1.3. Example: Practical design of printed antennas

2. Planar array antennas

- 2.1. Overview of planar array antennas
- 2.2. Phased array antennas
- 2.3. Example: Practical design of planar array antennas

3. Aperture antennas

- 3.1. Overview of advanced horn antennas
- 3.2. Overview of reflector antennas
- 3.3. Example: Practical design of aperture antennas

4. Reflectarray and Transmitarray antennas

- 4.1. Overview of reflectarray and transmitarray antennas
- 4.2. Analysis and design of transmitarray antennas
- 4.3. Analysis and design of reflectarray cells and reflectarray antennas
- 4.4. Techniques for bandwidth improvement
- 4.5. Contoured-beam reflectarrays
- 4.6. Dual-reflector configurations
- 4.7. Applications: Automotive radar, base station antennas, sub-mm waves, space antennas
- 4.8. Terahertz reflectarrays
- 4.9. New capabilities: filtering and non-reciprocal response
- 4.10. Reconfigurable and beam-scanning reflectarrays
- 4.11. Example: Practical design of reflectarray antennas

5. Antenna measurement techniques

5.1. Overview of antenna measurement systems

5.2. Far-field and Near-field measurement techniques

5.3. Source reconstruction and post-processing techniques

5.4. Laboratory with Matlab

6. Cronograma

6.1. Cronograma de la asignatura *

Sem	Actividad tipo 1	Actividad tipo 2	Tele-enseñanza	Actividades de evaluación
1	<p>Presentation and objectives of the course and Antenna project topics proposal Duración: 02:00 OT: Otras actividades formativas / Evaluación</p> <p>Topic 1: Printed antennas, overview of printed antennas Duración: 02:00 OT: Otras actividades formativas / Evaluación</p>			
2		<p>Task 1: Design of printed circular polarized antenna with CST Duración: 04:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		
3	<p>Topic 1 Printed antennas: Wideband and multiband printed antennas Duración: 02:00 LM: Actividad del tipo Lección Magistral</p>	<p>Task 1: Design of printed circular polarized antenna with CST Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		
4		<p>Task 2.1: Design of stacked patch antenna with CST Duración: 04:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		<p>Delivery before the start of the laboratory of a short report + final files for Task 1 TG: Técnica del tipo Trabajo en Grupo Evaluación Progresiva y Global Presencial Duración: 00:00</p>
5	<p>Topic 2 Planar array antennas: Phased arrays Duración: 02:00 LM: Actividad del tipo Lección Magistral</p>	<p>Task 2.2: Design of phased array antenna with MATLAB Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		
6		<p>Task 2.2: Design of phased array antenna with MATLAB Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio</p> <p>Task 2.3: Design of feeding network + array with CST Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		

7		<p>Task 2.3: Design of feeding network + array with CST Duración: 04:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		
8	<p>Topic 3 Aperture antennas: Overview of advanced horn antennas Duración: 02:00 LM: Actividad del tipo Lección Magistral</p>	<p>Task 3.1: Design of multimode horn antenna with CST Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		<p>Delivery before the start of the laboratory of a short report + final files for Task 2 TG: Técnica del tipo Trabajo en Grupo Evaluación Progresiva y Global Presencial Duración: 00:00</p>
9	<p>Topic 3 Aperture antennas: Overview of reflector antennas Duración: 02:00 LM: Actividad del tipo Lección Magistral</p>	<p>Task 3.2: Design of reflector + horn antenna with CST Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		
10	<p>Topic 4: Reflectarray and Transmitarray antennas, overview of reflectarray and transmitarray antennas, techniques for bandwidth improvement Duración: 02:00 LM: Actividad del tipo Lección Magistral</p>	<p>Task 3.1: Design of multimode horn antenna with CST Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		
11	<p>Topic 4: Reflectarray and Transmitarray antennas, overview of reflectarray and transmitarray antennas, techniques for bandwidth improvement Duración: 02:00 LM: Actividad del tipo Lección Magistral</p> <p>Topic 4: Reflectarray antennas, reconfigurable and beam scanning reflectarrays, Terahertz reflectarrays Duración: 02:00 LM: Actividad del tipo Lección Magistral</p>			
12		<p>Task 4: Design of reflectarray antenna with MRADANT-UPM software Duración: 04:00 PL: Actividad del tipo Prácticas de Laboratorio</p>		<p>Delivery before the start of the laboratory of a short report + final files for Task 3 TG: Técnica del tipo Trabajo en Grupo Evaluación Progresiva y Global Presencial Duración: 00:00</p>
13	<p>Topic 5: Antenna measurement techniques, overview of antenna measurement systems, Far-field and near field measurement techniques. Visit to anechoic chamber LEHA from ETSIT-UPM. Duración: 02:00 LM: Actividad del tipo Lección Magistral</p> <p>Topic 5: Antenna measurement techniques, source reconstruction techniques and post-processing techniques Duración: 02:00 LM: Actividad del tipo Lección Magistral</p>			

14		Task 5: Source Reconstruction Techniques Laboratory with Matlab Duración: 04:00 PL: Actividad del tipo Prácticas de Laboratorio		Delivery before the start of the laboratory of a short report + final files for Task 4 TG: Técnica del tipo Trabajo en Grupo Evaluación Progresiva y Global Presencial Duración: 00:00 Delivery of a short report + final files for Task 5 TG: Técnica del tipo Trabajo en Grupo Evaluación Progresiva y Global Presencial Duración: 00:00
15				
16				
17				Test exam about the content of each laboratory task EP: Técnica del tipo Examen de Prácticas Evaluación Progresiva y Global Presencial Duración: 01:00

Para el cálculo de los valores totales, se estima que por cada crédito ECTS el alumno dedicará dependiendo del plan de estudios, entre 26 y 27 horas de trabajo presencial y no presencial.

7. Actividades y criterios de evaluación

7.1. Actividades de evaluación de la asignatura

7.1.1. Evaluación (progresiva)

Sem.	Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
4	Delivery before the start of the laboratory of a short report + final files for Task 1	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	15%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
8	Delivery before the start of the laboratory of a short report + final files for Task 2	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	30%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
12	Delivery before the start of the laboratory of a short report + final files for Task 3	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	15%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03

14	Delivery before the start of the laboratory of a short report + final files for Task 4	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	7.5%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
14	Delivery of a short report + final files for Task 5	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	7.5%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
17	Test exam about the content of each laboratory task	EP: Técnica del tipo Examen de Prácticas	Presencial	01:00	25%	3 / 10	CB06 CB07 CB10 CT01 CT04 CE02

7.1.2. Prueba evaluación global

Sem	Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
4	Delivery before the start of the laboratory of a short report + final files for Task 1	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	15%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03

8	Delivery before the start of the laboratory of a short report + final files for Task 2	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	30%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
12	Delivery before the start of the laboratory of a short report + final files for Task 3	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	15%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
14	Delivery before the start of the laboratory of a short report + final files for Task 4	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	7.5%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
14	Delivery of a short report + final files for Task 5	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	7.5%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03

17	Test exam about the content of each laboratory task	EP: Técnica del tipo Examen de Prácticas	Presencial	01:00	25%	3 / 10	CB06 CB07 CB10 CT01 CT04 CE02
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7.1.3. Evaluación convocatoria extraordinaria

Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
Delivery before the start of the laboratory of a short report + final files for Task 1	TG: Técnica del tipo Trabajo en Grupo	Presencial	01:00	15%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
Delivery before the start of the laboratory of a short report + final files for Task 2	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	30%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
Delivery before the start of the laboratory of a short report + final files for Task 3	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	15%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01

						CE02 CE03
Delivery before the start of the laboratory of a short report + final files for Task 4	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	7.5%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
Delivery of a short report + final files for Task 5	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	7.5%	0 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
Test exam about the content of each laboratory task	EP: Técnica del tipo Examen de Prácticas	Presencial	01:00	25%	3 / 10	CB06 CB07 CB10 CT01 CT04 CE02

7.2. Criterios de evaluación

The evaluation will check if the students have acquired the competences of the subject. Therefore, the evaluation in the extraordinary call will use the same types of evaluation techniques that are used in the evaluation of the ordinary call (EX, ET, TG, etc.) and will be carried out on the dates and times of evaluation approved by the Junta de Escuela for the current subject and semester, except for those activities of evaluation of learning outcomes that are difficult to grade in a final test. In this case, such evaluation activities may be carried out throughout the subject. Evaluation will assess if students have acquired all the competences of the subject. Thus, evaluation through final assessment will be carried out considering all the evaluation techniques used in continuous evaluation (EX, ET, TG, etc.), and will be celebrated in the exam period approved by Junta de Escuela for the current academic semester and year. Evaluation activities that assess learning outcomes that cannot be evaluated through a single exam can be carried out along the semester.

Ordinary call:

The progressive evaluation will consists of the following

- 75% Report+simulation files delivered after each laboratory practices (LP), which is a mandatory activity that cannot be recovered. This activity is conducted in team groups of 2 or 3 students. The cross-evaluation among the team members is MANDATORY. The student who does not evaluate their classmates among the team members via Moodle will have a zero in the antenna project. The final grade for antenna project of members of the same team may be modified by the cross-evaluation process. **The average mark for laboratory tasks must be at least 5 points out of 10 to pass the subject.**
- 25% Test exam (TE): A short test will be executed individually at the end of the course about the details of each laboratory task to evaluate the knowledge acquired by each member of the team. **The mark for this test must be at least 3 points out of 10 to pass the subject.**

The final grade of the course will be calculated as $0.75*LP+0.25*TE$.

Due to the nature of this type of laboratory practices, in which specialized instrumentation and dedicated memories are required, the solutions of the laboratory practices will not be delivered in any case.

Any laboratory practices or antenna project delivered may require a complementary oral evaluation by the professors to validate that they have been done by the students without the help of artificial intelligence.

The evaluation of the antenna tasks will be done by means of the evaluation of the memory delivered in each laboratory and the evaluation via Moodle among the team members. The cross-evaluation among the team

members is MANDATORY. The student who does not evaluate their classmates among the team members via Moodle will have a zero in LP. The final grade for laboratory practices of members of the same team may be modified by the cross-evaluation process.

Extraordinary call:

- 75% Report+files delivered after each laboratory practices (LP), which is a mandatory activity that cannot be recovered. **The average mark for laboratory tasks must be at least 5 points out of 10 to pass the subject.**
- 25% Test exam (TE): A short test will be executed individually at the end of the course about the details of each laboratory task to evaluate the knowledge acquired. **The mark for this test must be at least 3 points out of 10 to pass the subject.**

Due to the nature of this type of laboratory practices, in which specialized instrumentation and dedicated memories are required, the solutions of the laboratory practices will not be delivered in any case.

Any laboratory practices or individual antenna project delivered may require a complementary oral evaluation by the professors to validate that they have been done by the student without the help of artificial intelligence.

Information about the Laboratory Practices:

- The skills acquired in the laboratory sessions in terms of handling antenna analysis and design tools cannot be acquired through any other type of methodology. For this reason, the completion of all the laboratory practices is a mandatory condition to pass the course. In other words, all the laboratory practices are mandatory activities.
- The completion of the laboratory sessions will be verified through the attendance to the laboratory and the delivery of the corresponding reports. In other words, it is essential to attend all the laboratory sessions and to hand in all the practical reports in order to pass the laboratory. Students who do not complete all the practical sessions will obtain a grade of NP (not presented) in the course.
- As they are mandatory activities that cannot be recovered, practices can only be carried out during the regular teaching period, in the laboratory and in the weeks scheduled in the practice calendar at the beginning of the course. It is not possible to do the laboratories telematically.
- Practices will not be recoverable due to the instrumentation necessary for the realization of the practices, the need for availability of laboratories, as well as the mandatory nature of the practices, among other logistical and academic reasons.

- The grade obtained in the laboratory practices will be used in the ordinary and extraordinary calls.
- Due to the nature of this type of laboratory practices, in which specialized instrumentation and dedicated memories are required, the solutions of the laboratory practices will not be delivered in any case.
- Any laboratory practices or antenna project delivered may require a complementary oral evaluation by the professors to validate that they have been done by the student without the help of artificial intelligence.

In no case, the grade of the laboratory practices or test exam can be transferred to the grade of successive years, closing a cycle with the extraordinary evaluation.

8. Recursos didácticos

8.1. Recursos didácticos de la asignatura

Nombre	Tipo	Observaciones
Design book	Bibliografía	Antenna Theory: Analysis and Design, C. Balanis, John Wiley & Sons, 4th Edition, 2016.
Microstrip antenna book	Bibliografía	Handbook of Microstrip Antennas, J.R. James, P.S. Hall, Peter Peregrinus Ltd, 1989.
Printed antenna book	Bibliografía	Advances in Microstrip and Printed Antennas, K. Fong Lee, W. Chen, Wiley, 1997.
Horns book	Bibliografía	Microwave Horns and Feeds, A.D. Oliver, P.J. Claricoats, A.A. Kishk, L. Shafai, IEE Electromagnetic Waves Series 39, 1994.
Reflectors book	Bibliografía	Modern Antenna Design, T.A. Milligan, IEEE Press, John Wiley & Sons, 2005.
Reflectarray design book	Bibliografía	Reflectarray Antennas, J. Huang and J.A. Encinar, IEEE Press, 2008.
Arrays book	Bibliografía	Phased Array Antenna Handbook, R.A. Mailloux, Artech House, 2005.
Measurement systems	Equipamiento	Anechoic chamber LEHA from Universidad Politécnica de Madrid
CST Studio Suite	Otros	Analysis and design of antenna software
Matlab	Otros	Mathematical software
MOOC Videos on Antennas	Recursos web	Massive Open Online Courses on Antennas available in the web (http://www.gr.ssr.upm.es/index.php/es/).

9. Otra información

9.1. Otra información sobre la asignatura

Students are recommended to download some software applications available in the UPM repository and in particular Matlab.

This subject can contribute to increase the awareness and training of our students in relation to the United Nations Agenda 2030 and its Sustainable Development Goals (SDGs). Some problems will show how various mathematical and electromagnetic tools are used in antenna modeling, which will allow students to become familiar with antennas for communications.

More generally, the applied concepts are used extensively in engineering and, in particular, will touch on everything related to telecommunication infrastructures (ODS 9). The course will also contribute to sub-objectives 4.4: To significantly increase the number of people with the professional and technical skills needed to access employment and entrepreneurship; and 4.7: To ensure that all students acquire the necessary theoretical and practical knowledge to promote sustainable development.