CROCEMS

COLLABORATIVE ROBOTICS FOR CIRCULAR ECONOMY IN MANUFACTURING SECTORS

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Identification of HE/VET programmes and competences related to CE and CR

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1 Introduction

CROCEMS is an ERASMUS+ project, that aims to fill a gap in vocational education and training and create a new course focusing on the introduction and implementation of circular economy in manufacturing sectors by using collaborative robotics to perform waste management.

In joint cooperation between the partners Atmoterm (Poland), CETEM (Spain), Deusto (Spain), Karlsruhe University of Applied Sciences - HKA (Germany), and Vienna University of Technology - TU Wien (Austria), the aim is to create and deliver a comprehensive training course on how to apply collaborative robotics to circular economy processes (sensor planning system for vision, reusable piece-recognition or disassembly of valuable materials) in order to boost the most effective waste management in European Manufacturing Sectors, helping to reduce its impact while creating job positions, enabling new manufacturing processes, business models and industrial symbiosis.

In this report, various higher education and vocational education and training (VET) programs related to the circular economy and collaborative robotics are discussed. The report examines the current situation in all partner countries and provides an overview of further training opportunities in both areas, circular economy, and collaborative robotics.

2 HE and VET Programmes related to Circular Economy

2.1 Spain

2.1.1 Summary of HE Programmes related to Circular Economy in Spain

Some of the examples founded in Spanish HE programmes are below:

- Degree in Environmental Sciences – University of Murcia
- Degree in Environmental Sciences - University of Castilla - La Mancha
- Degree in Environmental Sciences - University of Vigo
- Degree in Environmental Sciences - University of Granada
- Degree in Environmental Sciences - University of Salamanca
- Degree in Environmental Sciences - University of Cordoba
- Degree in Environmental Sciences - University of Zaragoza
- Degree in Environmental Sciences - Pablo de Olavide University
- Degree in Environmental Sciences - University of León
- Degree in Environmental Sciences - National University of Distance Education (UNED)
- Degree in Environmental Sciences - University of Girona
- Degree in Environmental Sciences - University of Cádiz
- Degree in Environmental Sciences - University of La Laguna
- Degree in Environmental Sciences - University of the Basque Country
- Degree in Environmental Sciences - University of Alcalá
- Degree in Environmental Sciences – University of Almería
- Degree in Industrial Technology Engineering – University of Sevilla (Subject: Waste Management and Treatment)
- Degree in Industrial Technology Engineering - uc3m
- Degree in Industrial Technology Engineering - UJI
- Degree in Industrial Technology Engineering - UPM

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- Degree in Industrial Technology Engineering – University of Oviedo
- Double Degree in Physics and Materials Engineering – University of Sevilla
- Master's Degree in Circular Economy and Sustainable Development
- Master's Degree in Circular Economy
- Master's Degree in Management, Treatment and Recovery of Organic Waste.
- Master's Degree in Environmental Management in Industry - University of Vigo

2.1.2 Summary of VET Programmes related to Circular Economy in Spain

- Higher Technician in Environmental Health
- Higher Technician in Environmental Chemistry

2.1.3 Conclusion

Spain's comprehensive educational offerings in both HE and VET sectors signify a strategic investment in building a skilled workforce capable of driving innovation, implementing Circular Economy principles, and contributing to the country's broader sustainability goals. By nurturing talent and expertise across diverse educational pathways, Spain is well-positioned to lead the way in promoting Circular Economy practices and fostering a more resilient and sustainable future.

Spain has demonstrated a robust commitment to fostering expertise and competence in the field of Circular Economy through its Higher Education (HE) and Vocational Education and Training (VET) programmes. The extensive array of HE programs across various universities, ranging from degrees in Environmental Sciences to Industrial Technology Engineering with a focus on waste management, reflects the country's recognition of the multidisciplinary nature of Circular Economy practices.

These HE programs not only equip students with theoretical knowledge but also offer practical insights and skills necessary for addressing contemporary environmental challenges. The inclusion of specialized master's degrees, such as those in Circular Economy and Sustainable Development, Management, Treatment, and Recovery of Organic Waste, underscores Spain's dedication to nurturing advanced expertise in sustainable resource management and circular business models.

Furthermore, the availability of VET programs, such as Higher Technician in Environmental Health and Environmental Chemistry, ensures that professionals at different stages of their careers have access to specialized training tailored to the specific needs of Circular Economy industries. These VET programs play a crucial role in bridging the skills gap and facilitating the transition towards a more resource-efficient and environmentally sustainable economy.

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2.2 Germany

2.2.1 Summary of HE Programmes related to Circular Economy in Germany

Table 1: HE programmes related to CE in Germany

Course	Duration	Type of Course
Bio- and Environmental Engineering	7 semesters	Bachelor's degree
Process Engineering – Energy, Environmental and Biotechnology	7 semesters	Bachelor's degree
Energy and Environmental Management	6 semesters	Bachelor's degree
Sustainability and Environmental Management	7 semesters	Bachelor's degree
Business Administration and Engineering – Environment and Sustainability	7 semesters	Bachelor's degree
Business Administration and Engineering – Circular Economy Engineering	7 semesters	Bachelor's degree
International Sustainability Management	7 semesters	Bachelor's degree
Sustainable Raw Material Production and Recycling	6 semesters	Bachelor's degree
Sustainable Engineering	7 semesters	Bachelor's degree
Sustainable raw material and energy supply	6 semesters	Bachelor's degree
Global Environmental and Sustainability	6 semesters	Bachelor's degree
Climate Change Management & Engineering	7 semesters	Bachelor's degree
Environmental and Resource Management	6 semesters	Bachelor's degree
Energy, Environmental and Process Engineering	6 semesters	Bachelor's degree
Energy and Environmental Engineering	6 semesters	Bachelor's degree
Eco Design	6 semesters	Bachelor's degree
Ecology and Sustainability Management	6 semesters	Bachelor's degree
Environmental Sciences	6 semesters	Bachelor's degree

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Environmental Technology	7 semesters	Bachelor's degree
Environmental and Recycling Technology	7 semesters	Bachelor's degree
Environment and Global Change	6 semesters	Bachelor's degree
Recycling and Waste Management	7 semesters	Bachelor's degree
Responsible Production and Consumption	7 semesters	Bachelor's degree
Renewable Raw Materials and Bioresources	6 semesters	Bachelor's degree
Environmental Engineering	6 semesters	Bachelor's degree
Environmental Systems Science	6 semesters	Bachelor's degree
Earth Sciences and Sustainable Management of Environmental Resources	6 semesters	Bachelor's degree
Ecology and Environmental Sciences	6 semesters	Bachelor's degree
Environmental Pollution Management - Ecotoxicology	4 semesters	Master's degree
Bio- and Environmental Engineering	3 semesters	Master's degree
Biological Resources	3 semesters	Master's degree
Sustainability and Circular Economy Management	4 semesters	Master's degree
Environmental and Recycling Technology	3 semesters	Master's degree
Sustainable Resource Management	4 semesters	Master's degree
Sustainable and Innovative Natural Resource Management	4 semesters	Master's degree
Sustainability and Climate Management	3 semesters	Master's degree
Sustainability Management and Technologies	3 semesters	Master's degree
Sustainability Science: Resources, Material and Chemistry	4 semesters	Master's degree
Environment, Climate Change and Health	4 semesters	Master's degree

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Process Energy and Environmental Systems Engineering	4 semesters	Master's degree
Eco Design	4 semesters	Master's degree
Energy and Environmental Management	4 semesters	Master's degree

2.2.2 Summary of VET Programmes related to Circular Economy in Germany

Table 2: VET programmes related to CE in Germany

Course	Duration	Type of Course
Mechanical engineering	3 years	School for Intermediate Vocational Education
Recycling and Waste Management	3 years	School for Intermediate Vocational Education
Environmental engineering	3 years	College for Higher Vocational Education
Mechanical engineering	3 years	College for Higher Vocational Education
Recycling and Waste Management	3 years	Advanced vocational qualifications
Mechanical engineering	3 years	Advanced vocational qualifications
Environmental Protection	3 years	Advanced vocational qualifications

2.2.3 Conclusion

In Germany, numerous bachelor's degree programs related to the circular economy are available at Vocational Education and Training (VET) and Higher Education (HE) institutions. The list provided represents a curated selection of the wide range of study options available. These courses focus on Environmental Engineering, Eco Design, Circular Engineering, Recycling and Waste Management,

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Responsible Consumption and Production, as well as Climate Change topics. The duration of these programs varies from 3 semesters to 3.5 years.

2.3 Austria

2.3.1 Summary of HE Programmes related to Circular Economy in Austria

Table 3: HE programmes related to CE in Austria

Course	Duration	Type of Course
Bio- and Environmental Engineering	6 semesters	Bachelor's degree
Energy and Environmental Management	6 semesters	Bachelor's degree
Global Sustainability and Circular Business	6 semesters	Bachelor's degree
Sustainable Production and Circular Economy	6 semesters	Bachelor's degree
Sustainable Resource Management	6 semesters	Bachelor's degree
Environmental, Process and Energy Engineering	6 semesters	Bachelor's degree
Circular Engineering	7 semesters	Bachelor's degree
Recycling Technology	7 semesters	Bachelor's degree
Responsible Consumption and Production	7 semesters	Bachelor's degree
Environmental and Bioresource Management	6 semesters	Bachelor's degree
Environmental and Climate Protection Technology	7 semesters	Bachelor's degree
Environmental Engineering	6 semesters	Bachelor's degree
Environmental Systems Science - Natural Sciences Technology	6 semesters	Bachelor's degree
Sustainability & Responsible Management	3 semesters	Master's degree
Bio- and Environmental Engineering	4 semesters	Master's degree
Digital Management & Sustainability	4 semesters	Master's degree
Eco Design	4 semesters	Master's degree

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Energy and Environmental Management	4 semesters	Master's degree
Ecotoxicology & Environmental Management	4 semesters	Master's degree
Environmental, Process and Energy Engineering	4 semesters	Master's degree
Circular Engineering	4 semesters	Master's degree
Environmental Sciences	4 semesters	Master's degree
Environmental Sciences - Soil, Water and Biodiversity	4 semesters	Master's degree
Environmental System Sciences - Climate Change and Environmental Technology	4 semesters	Master's degree
Environmental System Sciences - Climate Change and Environmental Technology (ESS/CCET)	4 semesters	Master's degree
International Master in Circular Economy	4 semesters	Master's degree
Recycling Technology	4 semesters	Master's degree
Responsible Consumption and Production	4 semesters	Master's degree
Material and Energy Use of Renewable Resources	4 semesters	Master's degree
Environmental and Bioresource Management	4 semesters	Master's degree
Environmental and Climate Protection Engineering	4 semesters	Master's degree
Environmental Engineering	4 semesters	Master's degree
Environmental Systems Science - Natural Sciences Technology	4 semesters	Master's degree
Water Management and Environmental Engineering	4 semesters	Master's degree

2.3.2 Summary of VET Programmes related to Circular Economy in Austria

Table 4: VET programmes related to CE in Austria

Course	Duration	Type of Course
Mechanical engineering - plastics and recycling technology	4 years	School for Intermediate Vocational Education

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Environmental technology	5 years	School for Intermediate Vocational Education
Environmental engineering	5 years	College for Higher Vocational Education
Plastics and environmental technology	5 years	College for Higher Vocational Education
Mechanical engineering - energy and environmental technology	5 years	College for Higher Vocational Education
Mechanical engineering - environmental engineering	5 years	College for Higher Vocational Education
Construction technology - environmental technology	5 semesters	Add-On Course
Mechanical engineering - environmental technology and recycling	6 semesters	Add-On Course
Renewable Energy, Environment and Sustainability	5 semesters	Add-On Course
Civil Engineering - Environmental Engineering	4 semesters	Post-secondary VET course
Mechanical Engineering - Environmental Technology and Recycling	6 semesters	Post-secondary VET course
Renewable Energy, Environment and Sustainability	4 semesters	Post-secondary VET course

2.3.3 Conclusion

In Austria there are several courses related to Circular Economy offered by VET and HE institutions. The list of courses is a selection and is not exhaustive. These courses focus on Environmental Engineering, Eco Design, Circular Engineering, Recycling Technology, Responsible Consumption and Production as well as Climate Change topics and can be done in between 4 semesters and 5 years, full-time or part time depending on the course type from schools for intermediate vocational education (ISCED 3), to master's degrees (ISCED 7) or even higher.

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2.4 Poland

2.4.1 Summary of HE Programmes related to Circular Economy in Poland

Higher studies in the field/specialization of Circular Economy are conducted in several academic centers in Poland. Two examples are described below - one for studies at the Faculty of Production Engineering and the other for studies at the Faculty of Environmental Engineering.

Example 1: University of Life Sciences in Lublin - specialized engineering studies (1st cycle - BSc) in the Circular Economy at the Faculty of Production Engineering.

Circular Economy is a modern, practical field of study of an engineering and technical nature, preparing graduates in the use of knowledge and engineering processes to introduce and monitor the functioning of the mechanisms of the regenerative economic system. The content of education in the field of Circular Economy includes issues from the field of engineering, technology and natural sciences, and above all from the disciplines of mechanical engineering and environmental engineering, mining and energy.

Example 2: Wrocław University of Science and Technology - master's studies (2nd cycle - MSc) - Circular Economy and climate protection at the Faculty of Environmental Engineering.

As part of the Circular Economy specialization, students acquire knowledge in the following areas:

- politics, Circular Economy and climate change;
- sustainable management of raw materials;
- water and sewage management;
- technologies for processing biodegradable, industrial and hazardous waste;
- processing and recycling of plastics;
- life cycle assessment of products and processes.

2.4.2 Summary of VET Programmes related to Circular Economy in Poland

According to available information a VET offer related to Circular Economy is rather limited. VET programs include a course organized by the Polish Agency for Enterprise Development (PARP) for entrepreneurs interested in adopting the Circular Economy model: "Circular Economy in SMEs". This is a short 5-hour introductory course intended for producers and service providers. The course is complemented by a webinar "Circular Economy - how to implement a circular waste management model in the enterprise".

2.4.3 Conclusion

At the university level, the thematic scope of Circular Economy is offered in several academic centers, both as independent fields of study and as part of broader programs. The offer at VET level is rather limited to short courses of a general nature.

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3 Conclusion related to Circular Economy

Various higher education and vocational education and training (VET) programs related to the circular economy are offered in partner countries like Poland, Austria, Spain and Germany. These programs cover a wide range of topics such as Environmental Engineering, Eco Design, Circular Engineering, Recycling Technology, Responsible Consumption and Production, and Climate Change. Those programmes and courses offers a wide array of educational pathways to cultivate talent and expertise in sustainable resource management and circular business models.

The duration of these programs varies from short courses to bachelor's degrees and master's degrees, with a focus on equipping students with both theoretical knowledge and practical skills necessary for addressing contemporary environmental challenges. The comprehensive educational offerings in these countries reflect a strategic investment in building a skilled workforce capable of leading the way in promoting environmentally sustainable practices and fostering a more resilient future.

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4 HE and VET Programmes related to Collaborative Robotic

4.1 Spain

4.1.1 Summary of HE Programmes related to Collaborative Robotic in Spain

- Degree in Artificial Intelligence - Polytechnic University of Catalonia
- Degree in electronic and automatic engineering + robotics - European University of Madrid
- Degree in Artificial Intelligence - University of the Basque Country
- Degree in Robotics Engineering - University of Deusto
- Degree in Industrial Electronics and Automation Engineering - University Carlos III of Madrid (UC3M)
- Degree in Industrial Systems Engineering - University Francisco de Vitoria (UFV) Madrid
- Master's Degree University Expert in Industrial Robotics and Emerging Technologies - University of Burgos
- Master's Degree in Digital Business Transformation - International University of Andalucia
- Master's Degree in Control, Automation and Robotics Engineering - University of the Basque Country
- Master's Degree in Robotics Management in Businesses - Rovira i Virgili University
- Master's Degree in Robotics - IGEMA, University Study Centre
- Master's degree in digital transformation of companies - University of Almeria
- Master's Degree in Robotics and Intelligent Systems - University of Vic (Uvic) and Technology Centre of Catalonia (Eurecat)
- Master's Degree in Industry 4.0 - University of Alcalá (Madrid)
- Master's Degree in Industry 4.0 (interuniversity: UOC, ESUPT) - Oberta University (Catalonia)
- Master's degree in industry 4.0 - Polytechnic University of Cartagena (UPCT)
- Master's Degree in Digital Manufacturing - University of the Basque Country (UPV)
- Master's Degree in Connected Industry - University of Jaén (UJA)
- Master's Degree in Connected Industry 4.0 - Carlos III University of Madrid (UC3M)
- Master's Degree in technologies applied to Industry 4.0 - University of Salamanca (USAL)
- Master's Degree in Robotic Architecture and Emerging Technologies - University of Malaga
- Master's Degree in Control Engineering, Automation and Robotics - University of the Basque Country

4.1.2 Summary of VET Programmes related to Collaborative Robotic in Spain

- Industrial Automation and Robotics
- Collaborative robotics and machine vision for Industry 4.0
- Higher Level Training Cycle in Industrial Automation and Robotics
- Higher Technician in Industrial Automation and Robotics
- Specialization Course in Collaborative Robotics (GS Access)

4.1.3 Conclusion

Spain has made significant strides in fostering expertise and proficiency in collaborative robotics through its comprehensive array of Higher Education (HE) and Vocational Education and Training (VET) programs. The diverse HE programs offered by esteemed universities across the country cater

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to a broad spectrum of disciplines, reflecting the interdisciplinary nature of collaborative robotics and its intersection with fields such as artificial intelligence, engineering, and digital transformation.

These HE programs equip students with both theoretical knowledge and practical skills essential for navigating the complexities of collaborative robotics in various industrial settings. Specialized master's degrees, such as those in Industrial Robotics and Emerging Technologies, Robotics Management in Businesses, and Control Engineering, Automation, and Robotics, demonstrate Spain's commitment to fostering advanced expertise in this rapidly evolving domain.

Additionally, the availability of VET programs focusing on collaborative robotics ensures that professionals at different career stages have access to specialized training aligned with the demands of Industry 4.0. These VET programs play a pivotal role in bridging the skills gap and preparing individuals to harness the potential of collaborative robotics for enhancing productivity and driving innovation in modern industries.

4.2 Germany

4.2.1 Summary of High Education programmes related to Collaborative Robotics in Germany

Table 5: Options of HE programmes related to CR in Germany

Study Programme	Robotics in Higher Education	
Type of course (Master, degree, independent course, etc.)	Bachelor Degree	Master's degree
Duration	6 to 7 semesters	3 to 4 semesters
Number of universities offering the programme	14	18

Various courses are also offered in the field of Vocational Education and Training (VET).
The study contents in the Bachelor's programme include:

- Fundamentals of electrical engineering
- Electronic components and circuit technology
- Electrical Measurement
- Digital technology
- Microcomputer Technology
- Electrical Drives and Networks
- Signals and Systems
- Fundamentals of control and regulation technology
- Control and power converter technology
- Kinematics and control of robots
- Image processing

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- Motion Control
- Hardware and software design in automation technology
- Simulation techniques
- Design of mechatronic systems
- Control technology and industrial bus systems
- Technology of CNC-controlled machine tools
- Robot programming
- Practical control engineering

In the master's programme, there are different specialisations to choose from:

- Mobile Robots, Autonomous Systems and Robot Vision
- Fibre composites and special materials
- Optical sensor technology, computer vision
- Control Engineering
- Electric drives and gear technology
- Embedded Systems

In Germany, training is also offered by robot manufacturers or independent service providers. A summary of the contents with the numbers of courses offering the corresponding is shown in the table below (the contents are grouped in thematic categories).

Table 6: Overview of HE programmes offered by robot manufactures & independent service provider

Content			No.
Knowledge			
	HRC Basics		
		Introduction to HRC / basics and terms (e.g. operating modes, singularities, sensitivity)	13
		Challenges / risks / limits	9
		Opportunities / Goals / Advantages	8
		Examples / use of LBR in collaboration Requirements for cobots (safety-related, ergonomic, biomechanical)	5
		Concept / Layout / Integration	7
		Evaluation (economic efficiency, technical, ergonomics)	4
	Standards/Safety/CE		

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		EN ISO 12000 / Risk Assessment	12
		DIN EN ISO 10218-1 and -2	9
		DIN ISO/TS 15066	7
		CE certification / MRL	5
		Standards in general (incl. PL)	9
		Planning the cell (safe)	6
		Acceptance protocol / Documentation / Verification and validation / Approval process of new installations / User information	5
		Occupational safety (safety instructions, knowing the dangers of handling robots, etc.)	16
		Robot safety / safe handling of robots / safe operation	6
		Safety, ergonomic, biomechanical requirements	1
		Force and pressure measurement / Biomechanical limits	4
		Safety technology (safety scanner, light barrier, etc.)	20
Programming Robots			
	Safety Functions		
		Safety functions (reduced mode, stop function, etc.)	18
		Set hazardous areas / Secure areas / Safety distances	18
		Security settings	15
	Human-machine communication		
		Recognise and understand messages (error messages, diagnosis, warning messages)	11
		Query process data / Query robot position	4
		Programming, setting and querying inputs and outputs	10
		Data backup / Loading and saving the data	7

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		Operating handset / Operation / SmartPAD	6
	Moving the robot manually		
		Moving the robot (axis-specific, straight-line, zero space) / teaching / approaching frames / hand guiding	15
	Interaction with external peripherals		
		Gripping technology (installing, handling, measuring, load data, operating, calibrating etc.)	16
	Application development		
		Specific application development (screws, conveyor belt, pick & place)	11
	Programming - movements		
		Speed / looping / acceleration / relative to coordinate system / teach-in positions / create general movement programmes	18
	Programming - logic		
		Conditions / Loops / Variables / IF-Else	18
	Programming Robots		
		Conditions / Loops / Variables / IF-Else	18
		Thread	10
		Coordinate systems (explanation, creation, etc.)	11
		Robot programmes (create, modify, start, stop, optimise)	23
		Basic commands (change and delete instructions, create functions [general, switch cancel functions])	7
		Specific commands (timers, alarms, calculations, frame shifts, user keys, etc.)	10
		Programming errors / programme sequence controls / debugging	4
	Programming - native language		
		Basics of textual programming languages (Java, Python, XML, ROS)	4

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	Communication interfaces		
		Communication between robot and tool	7
		Communication interfaces (socket, client interfaces, FTP server, EtherCat, bus systems, IO, etc.)	8
	Movement types		
		Movement types (manual and automatic mode, waypoints, etc.)	13
		Program and understand movement types (PTP, LIN, robot specific, etc.)	5
	Force Control		
		Understanding and programming force control/reading out torques and forces/impact of load data/programming search functions	17
Robot mechanics			
	Setup/Configuration		
		Integration / setup of sensors (e.g. camera)	6
		Robot commissioning / station / basic setting of a robot / calibration / adjustment / set-up / connection	12
	Basics Structure, hardware and software		
		Structure and mode of operation of a robot (electrical, mechanical, controller, etc.)	29
		Control concept	2
		Differences robots	2
		Maintenance/ servicing	2

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A summary of training courses can be found in the following table.

Table 7: summary of training courses related to HE programmes

Universal Robots Academy	e-Series Core Track e-Series Pro Track e-Series Application Track E-Learning für CB3-Roboter Core Training Advanced Training Interfaces Training Industrial Communications Training Service & Troubleshooting Training Script Training Safety Training
KUKA College	Robot operation Sunrise OS 1 Robot operation PRO LBR iiwa Sunrise OS 1 Installation and programming Sunrise OS 1 Safety installation and HRC programming Sunrise OS 1 HRC-Engineering Workshop Service Elektrik KUKA Sunrise Cabinet Constructor Sunrise OS 1
Yaskawa	Operator training Weld4me Basic Training Weld4me Collaborative operator training Collaborative Basic Training YRC Generation Upgrade Training HC FSU Safety Controller Training YRC1000 HC Customer Advisory Part 1 - Legal Framework HC Customer Advisory Part 2 - Functional Safety FSU

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	HC customer advisory service Part 3 - Machine safety MS and force-torque limit PFL HC10 basics with YRC1000micro HC10 basics with YRC1000micro + Smart Pendant
Omron	TC114 - Robotics - Operation and Programming
DENSO Robotics Europe	Cobotta World Training Cobotta Basic Training Advanced Training
IHK Akademie	Human-Robot Collaboration (HRC): But Safe!
	Human-Robot Collaboration (HRC): But Safe!
Röder Training	Human-robot collaboration: requirements, potentials and solutions
Fraunhofer Academy	Human-Robot Collaboration (HRC) | Continuing Education
Haus der Technik e. V.	Qualified person for the inspection of industrial robots - HRC - Mensch-Roboter-Kollaboration-Industrie 4.0
HLS COBOT World	HRC-Training
TÜV Süd Akademie	Robotics - Automation and Industry 4.0 - Your introduction to the automation of robotic systems
TÜV Rheinland	Industry 4.0: Robotics Workshop - Seminar on using ROS to control collaborative robots.
Allgemeine Unfallversicherungsanstalt	Specialist seminar "Human-Robot Collaboration (HRC)"
	Specialist seminar "Human-Robot Collaboration in the Smart Factory"
Pilz GmbH & Co. KG	Safe human-robot collaboration HRC
BFI Steiermark	Safe HRC systems: human-robot collaboration
Bildungswerk der Bayerischen Wirtschaft (bbw)	Robotics 4.0 - module of the "Industry 4.0" qualification series

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Festo Lernzentrum Saar GmbH	Industry 4.0 - from multimodal human-robot collaboration to teamwork between humans and robots
FANUC Academy Germany	Basic course (collaborative robots)
SICK GmbH	Training: Safe HRC systems: human-robot collaboration
ILT Institut für Laborautomation und Mechatronik	Collaborative Robotics in Practice - Standard Course

4.2.2 Summary of VET programmes related to Collaborative Robotics in Germany

In Germany, there are facilities for education in robotics both already for the school sector and various courses of study in robotics to impart an understanding of the technology at an early stage. Learning robotics already at school is supported by the following providers:

Table 8: VET programmes related to CR in Germany

Name	Content	Age	Website
Cubetto	Teaches the elementary basics of programming by controlling a wooden robot by placing different wooden stones on a wooden board. Young children learn programming through play - without a screen or the necessary reading skills.	3-6 years	www.primotoys.com
Dash and Dot	Pre-designed models offer different applications and programming possibilities depending on age and experience level	5-11 years	wonder-workshop.de
Ozobot	Mini robot Ozobot can perform various movements and manoeuvres. Commands via self-painted colours and lines detected by several sensors or via programming language using the mobile app.	6-16 years	ozobot-deutschland.de

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LEGO Education - WeDo 2.0	With the versatile LEGO kit, different models and machines can be built and programmed with the graphical programming software WeDo 2.0 via PC and mobile devices.	7-14 years	education.lego.com
Cozmo	Focus on direct interaction with people. prefabricated robot can be programmed via app, can move independently and can make contact with pupils. Different programming modes offer different possibilities depending on the level of knowledge and help especially with the transition from graphical programming to code.	8-16 years	www.digitaldreamlabs.com
B-O-B 3	Mixture of microcontroller and immobile mini robot can be programmed graphically or code-based according to the learners' level of experience.	8-16 years	www.bob3.org/de
mBot	Robot kit Getting to know the structure and technical elements of robots. Scratch-based graphical programming language mBlock.	8-16 years	www.makeblock.com
Bot'n Roll	Programming via the graphical programming language of the Open Roberta Lab or via code. Sophisticated design and programming	11-19 years	www.botnroll.com
LEGO Education – Mindstorms	Enables the flexible construction and programming of a wide variety of pre-constructed and own models and mechanical devices. High complexity of building and programming possibilities	11-19 years	education.lego.com

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A company that specialises in bringing robotics to children in the classroom and through holiday camps:

Table 9: Overview - Robot School for Children

Course name	Robot School for Children
Type of course (Master, degree, independent course, etc.)	School Education
Entity	Robot School
Information	• Over 24 partner schools • Offer 86 holiday programmes
Content	Teach basic knowledge and the basics about programming languages. Step-by-step introduction to programming. Children are introduced to the topic of robotics and robot building and programming step by step in an age-appropriate way. As the level and difficulty increases, topics such as electronics, design, 3D printing and individual programming with complex programming languages are taught.
Link	https://www.robot-school.de/

4.2.3 Conclusion

In Germany, various courses related to Robotics and Automation are provided by Vocational Education and Training (VET) institutions, Higher Education (HE) institutions, and companies. These HE programs provide students with both theoretical knowledge and practical skills necessary for navigating the complexities of collaborative robotics in different industrial settings. Specialized master's programs with various specializations such as Mobile Robots, Autonomous Systems, and Robot Vision, Fibre Composites showcase Germany's dedication to cultivating advanced expertise in this rapidly evolving field. Another special feature is the focus on children in order to introduce them to robotics topics at an early age and create interest and awareness for the subject. The list of courses presented is a curated selection and not comprehensive. These programs concentrate on Robotics, Mechatronics, Artificial Intelligence, Smart Engineering, and Industry 4.0. The duration of these courses typically ranges from 4 to 7 semesters.

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4.3 Austria

4.3.1 Summary of HE programmes related to Collaborative Robotics in Austria

Table 10: HE programmes related to CR in Austria

Course	Duration	Type of Course
High Tech Manufacturing (BSc)	6 semesters	Bachelor's degree
Industrial Mechatronics	6 semesters	Bachelor's degree
Intelligent Production Technology	6 semesters	Bachelor's degree
Mechatronics	6 semesters	Bachelor's degree
Mechatronics - Microsystems Technology	6 semesters	Bachelor's degree
Mechatronics - Robotics	6 semesters	Bachelor's degree
Mechatronics, Design & Innovation	6 semesters	Bachelor's degree
Robotics	6 semesters	Bachelor's degree
Smart Automation	6 semesters	Bachelor's degree
Smart Engineering of Production Technologies and Processes	6 semesters	Bachelor's degree
Mechatronics	7 semesters	Bachelor's degree
Mechatronics (B.Eng.)	6 semesters	Bachelor's degree
Artificial Intelligence (BSc)	6 semesters	Bachelor's degree
Mechatronics (BA)	6 semesters	Bachelor's degree
Robotics and Artificial Intelligence	6 semesters	Bachelor's degree
AI for Sustainable Technologies	4 semesters	Master's degree
Data Science and Artificial Intelligence	4 semesters	Master's degree
Digital Technology & Innovation	4 semesters	Master's degree
High Tech Manufacturing (MSc)	4 semesters	Master's degree

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Industrial Informatics & Robotics	4 semesters	Master's degree
Mechatronics (MSc)	4 semesters	Master's degree
Mechatronics - Additive Manufacturing (AM)	4 semesters	Master's degree
Mechatronics - Mechatronic Systems	4 semesters	Master's degree
Mechatronics - Smart Technologies	4 semesters	Master's degree
Robotic Systems Engineering	4 semesters	Master's degree
Robotics Engineering	4 semesters	Master's degree
Artificial Intelligence (MSc)	4 semesters	Master's degree
Artificial Intelligence and Cybersecurity	4 semesters	Master's degree
Information and Communications Engineering - Autonomous Systems and Robotics	4 semesters	Master's degree
Mechanical Engineering - Mechatronics	4 semesters	Master's degree

4.3.2 Summary of VET Programmes related to Collaborative Robotics in Austria

Table 11: VET programmes related to CR in Austria

Course	Duration	Type of Course
Mechatronics - main module automation technology	4 years	Apprenticeship
Mechatronics - main module production engineering	4 years	Apprenticeship
Mechatronics - automation technology	4 years	School for Intermediate Vocational Education
Mechanical engineering - automation technology - mechatronics	5 years	College for Higher Vocational Education

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Mechanical engineering - robotics and smart engineering	5 years	College for Higher Vocational Education
Mechatronics - Automation	5 years	College for Higher Vocational Education
Mechatronics - Dynamic Systems	5 years	College for Higher Vocational Education
Mechatronics - Industry 4.0	5 years	College for Higher Vocational Education
Mechatronics - Innovation	5 years	College for Higher Vocational Education
Mechatronics - Robotics	5 years	College for Higher Vocational Education
Mechatronics - Robotics and Handling	5 years	College for Higher Vocational Education
Mechanical engineering - Robotic Center	7 semesters	Add-On Course
Mechanical engineering - robotics	8 semesters	Add-On Course
Mechatronics	7 semesters	Add-On Course
Mechatronics - automation technology	6 semesters	Add-On Course
Mechatronics	4 semesters	Add-On Course
Mechanical engineering - automation technology	4 semesters	Industrial Master College
Mechatronics	6 semesters	Post-secondary VET course

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Mechatronics - automation technology	6 semesters	Post-secondary VET course
Mechatronics	4 semesters	Post-secondary VET course

4.3.3 Conclusion

In Austria there are several courses related to Robotics and Automation offered by VET and HE institutions. The list of courses is a selection and is not exhaustive. These courses focus on Robotics, Mechatronics, Artificial Intelligence, Smart Engineering and on Industry 4.0. The courses can be done in between 4 semesters and 5 years, full-time or part time depending on the course type, from apprenticeships (ISCED 3) to master's degrees (ISCED 7) or even higher.

4.4 Poland

4.4.1 Summary of High Education programmes related to Collaborative Robotics in Poland

CR is an element of full-time higher education and postgraduate studies in the fields of 'Automation and Robotics' in several academic centers in Poland. Two examples are described below - from Rzeszów and Wrocław.

Example 1: University of Rzeszów

As part of the 'Fundamentals of robot programming' course, students will learn about the following topics:

- historical outline of the development of robotics and robot programming techniques;
- kinematics of industrial robots
- robot construction
- robot programming
- review of robot applications (including CR)
- the state of robotization in Poland and in the world.
- current trends in robotics.

Example 2: Wrocław University of Science and Technology

As part of the 'Robot Collaboration' course, students will learn about the following topics:

- types of collaborative robots
- advantages and disadvantages of cooperation
- elements of safety systems in CR
- review of suppliers of collaborative robots
- current applications and development directions

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4.4.2 Summary of VET Programmes related to Collaborative Robotics in Poland

The offer of VET programs in the field of collaborative robots includes specialized training courses. An example is the training program offered by the Engineering Training Center, which includes training on robots produced by:

- FANUC,
- ABB,
- KUKA,
- Wittmann,
- COMAU.

4.4.3 Conclusion

CR is an element of full-time higher education and postgraduate studies in the fields of 'Automation and Robotics' in several academic centers in Poland. The offer of VET programs in the field of collaborative robots mainly concerns specialized training courses.

5 Conclusion related to Collaborative Robotics

Spain, Germany, Austria, and Poland offer a variety of Higher Education (HE) and Vocational Education and Training (VET) programs focused on Collaborative Robotics and Automation. These programs cover topics such as collaborative robotics, mechatronics, artificial intelligence, smart engineering, and Industry 4.0.

Students in these programs gain theoretical knowledge and practical skills essential for navigating the complexities of robotics in industrial settings. Specialized master's degrees demonstrate a commitment to fostering advanced expertise in this rapidly evolving field. VET programs play a crucial role in bridging the skills gap and preparing professionals to leverage robotics for productivity and innovation in modern industries across these countries.

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