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"Innovation Garage of Garages"

IO1 – Intellectual Output 1

Train-the-trainer programme for the development of the Innovation Garage in the workplace as a situated learning environment

Output Type: Methodologies/Guidelines – Non formal learning methods

OER – Open Educational Resource

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Train-the-Trainer Program: how to train VET learners on EV/BEV/HEV/PhEV Vehicles

Language: English

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Innovation Garage of Garages

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1.Developing green mobility skills at VET level in the Automotive Sector

Transportation and mobility sector is a strategic asset for the EU competitiveness, both for employment and citizen service purposes, yet it urgently needs measures to reduce emissions and to increase the use of alternative fuels for vehicles.

The main programmatic document for the EU strategy towards sustainability is the **European Green Deal**, first published by the EC in 2019, outlining the following objectives:

-Leading the third industrial revolution through improving buildings and infrastructure, through massive use of electrification and green alternative renewable energy;
-Making transportation more sustainable, with at least 30 million zero-emission cars in operation on European roads by 2030;
-Producing zero emission large aircraft vehicles by 2035;
-Having 90% zero-emission private, public and commercial transportation vehicle park by 2050 across the EU.

According to the 2020 "Sustainable and Smart Mobility Strategy" and Action Plan, the EU vision towards **Green Mobility** relies upon different and complementary pillars, namely **sustainability**, through the spread of renewable and fossils-free fuel, and **digitalization**, through the use of energy-efficient, interconnected and multi-modal mobility means, thanks to the potentiality of IT and communication technology.

Lately, the European Green Deal strategy was also further boosted by the 2023 EU Parliament majority vote to stop the production and sales of endothermic engine vehicles from 2035 onwards.

Information Focus: The European Green Deal

In this section the teacher/trainer will find direct links to informative and educational sources about the European Green Deal text, annexes and commentary materials:

EU Green Deal Paper (English)
EU Green Deal Information Page by the European Commission (English)
Annex to the EU Green Deal Communication (English)

A short yet summative video by the EC on the EU Green Deal is also available:

The European Green Deal - A Committment to Future Generations

Educational Videos about the main mobility-related topics within the EU Green Deal:

Transport

EU Emission Trading System

Energy

Car Emissions

The “Fit for 55” is a set of proposals to revise and update EU legislation and to put in place new initiatives with the aim of ensuring that EU policies are in line with the climate goals agreed by the Council and the European Parliament.
Fit for 55 refers to the EU’s target of reducing net greenhouse gas emissions by at least 55% by 2030. The proposed package aims to bring EU legislation in line with the 2030 goal.

Review of the EU ETS «Fit for 55 package»

Following the COVID19 pandemic crisis, the EC also launched the **Next Generation EU** initiative, which is way more than a recovery plan: worth more than 806 billion Euro, it is a vision and strategy to transform the EU economy towards a greener, more digital and more inclusive society.

Among the main elements in the package, those most relevant for the expected impact on the mobility sector are:

- fighting climate change, with 30% of the EU funds, the highest share ever of the European budget
- fair climate and digital transitions, via the Just Transition Fund and the Digital Europe Programme

The EC is also releasing **scoreboard** documentation to track and measure how the entire Europe and the single countries are doing in terms of efforts and investments towards the goals of both the Recovery Plan and the Green Deal.

The “Green Transition” Pillar includes some charts showing that sustainable mobility has the biggest proportion of expenditures across the EU towards climate objectives and green transition across the EU:

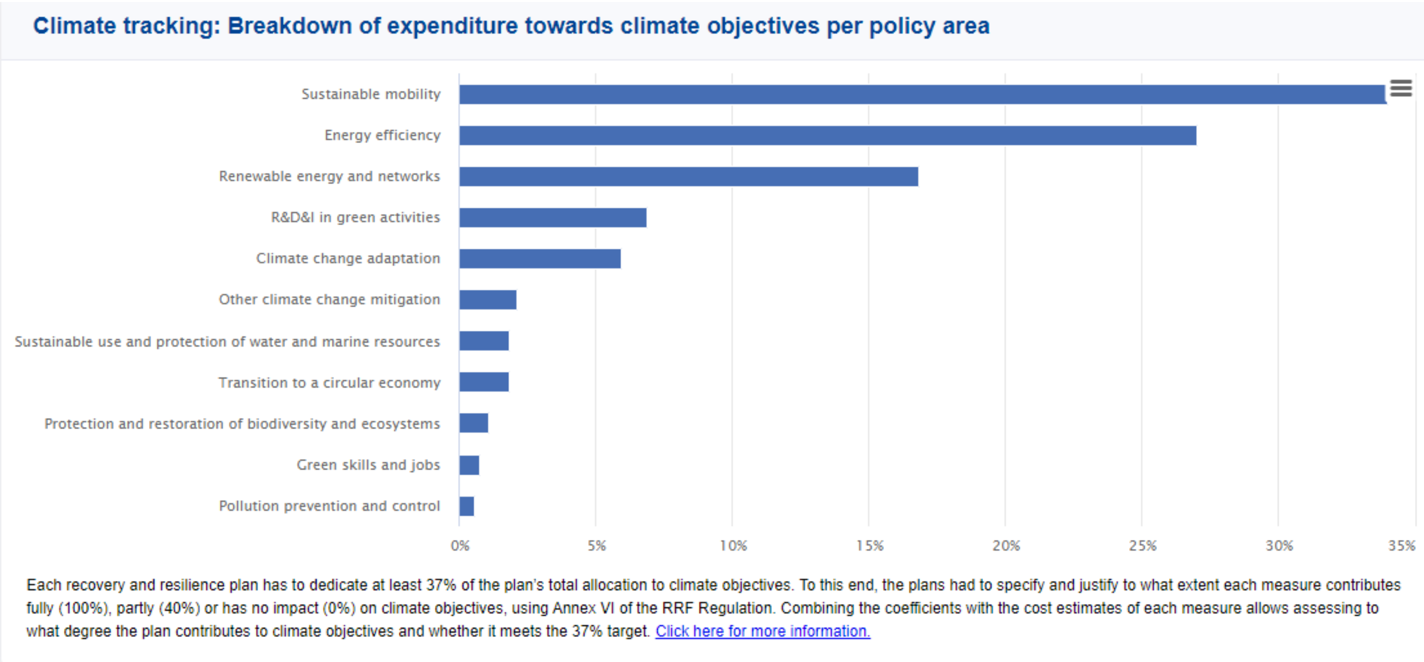


Image Source: EU Recovery and Resilience Scoreboard

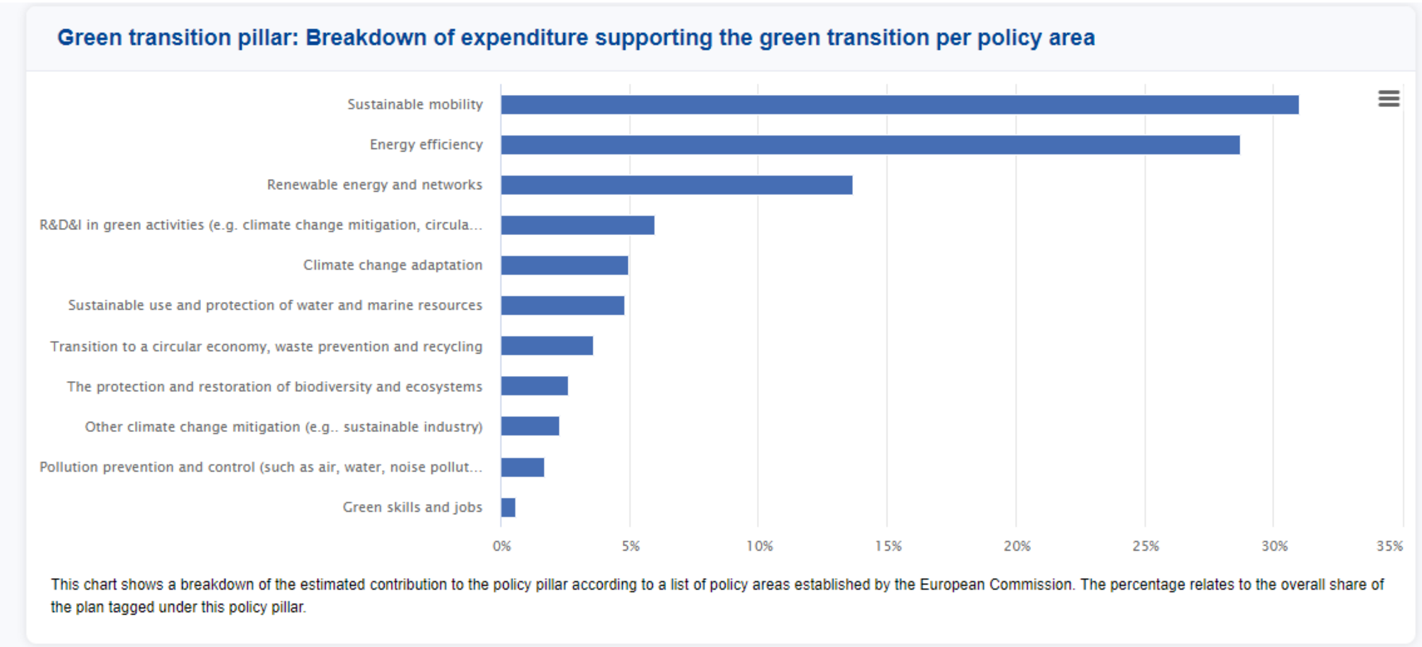


Image Source: EU Recovery and Resilience Scoreboard

Furthermore, the Thematic Analysis report on S**ustainable Mobility**, explains that Member States are working on increasing policies and money investments to improve the alternative and renewable fuels infrastructures and to promote **zero or low emission** mobility through support to e**lectric and hybrid vehicles** (both for private and commercial purposes). In this scenario, 7,6 billion euro investments will increase the network of electric charging stations across the EU.

This is where education, and in particular VET at all levels, from I-VET to H-VET to C-VET, comes into play. VET is a valuable asset for the development of industry-related and job-related skills, in particular to bridge the gap between the offer, represented by the world of education and training at all levels, and the demand, represented by the sector-specific job market.

The VET sector has plenty of contributions to offer to the development of Green Skills for the automotive sector, thanks to the strong relationships it holds with the companies and stakeholders, and to the chance to co-design training programs through work-based learning in a real workplace environment or virtual simulation.

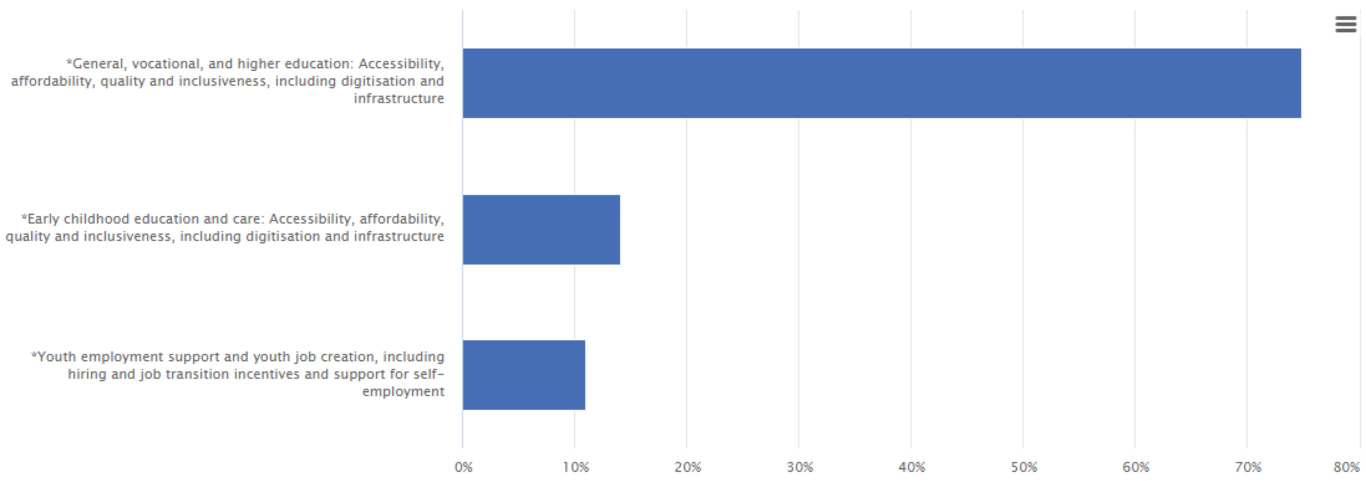
Furthermore, 2023 is celebrated as the European Year of Skills, which strives to empower both individuals and companies, especially SMEs, to contribute to the green and digital transitions, supporting innovation and competitiveness. The goal is to address the skills shortage across the EU in strategic industrial sectors, to boost the competitiveness of member states through initial training, upskilling and/or reskilling of workers, also as away to fight social exclusion and to promote civic engagement and social cohesion, preventing educational failure, unemployment and ultimately, radicalization. A key asset of such strategy relies on making sure that skills are relevant for the labour market needs, while more than three quarters of companies in the EU say they have difficulties finding workers with the necessary skills, while only 37% of adults undertake training on a regular basis.

On the other hand, such initiative just puts in practice the goals of the European Skills Agenda, betting on the potential and urgency of green and digital skills to lift Europe up as a resilience factor after the Covid19 pandemic, both by building education and training capacity to support the uptake of new skills, and by encouraging individuals to pursue highly qualified VET paths.

The Recovery and Resilience Scoreboard gives an overview of the pillar names “Policies for the next generation, children and the youth, such as education and skills”, where it is clear than priority is given to a quality education at all levels, including the digitalization of the infrastructure, as well as to the creation of high quality job opportunities, especially for young people entering the labour market.

Within the Recovery and Resilience Scoreboard charts, the Thematic Analysis on Education illustrates measures across the EU to support the entire education system, fighting educational failure, and boosting vocational and tertiary education, with a focus on science, technology, engineering, and mathematics skills and the participation of women. Additional measures include a reform of the educational guidance system, increasing mentoring activities to ease the transition from school to the labour market, youth employability and social cohesion with particular attention to the green and digital transition.

Breakdown of expenditure supporting policies for the next generation per policy area



This chart shows a breakdown of the estimated contribution to the policy pillar according to a list of policy areas established by the European Commission. The percentage relates to the overall share of the plan tagged under this policy pillar. The methodology for reporting social expenditure, as defined in Delegated Regulation (EU) 2021/2105, is fully aligned and integrated into the methodology for reporting expenditure under the six pillars. Under this pillar, the policy areas marked with an asterisk (*) are used for the social expenditure methodology.

Image Source: EU Recovery and Resilience Scoreboard

In a similar way, the Thematic Analysis on Employment shows a joint effort, from all member states, to support job creation and the modernisation of the labour market, by improving the accessibility of quality job roles, especially from disadvantaged or vulnerable groups, such as young people, women, aged workers, by establishing measures to equip individuals with green and digital skills empowering them to contribute to the competitiveness of the whole national and EU economic system.

This overall political, economical and social post-pandemic scenario across the EU represents the general context where the automotive sector is jointly putting big efforts to recover from forced lockdown during the first phase of Covid19, and to face the threatens posed to the global automotive supply chain by the recent breakthrough of conflict in Eastern Europe.[1]

Exploiting the potential of the green, low or zero-emission engines and fuels, as well as on the digital connectivity of vehicle fleets, the Innovation Garage of Garages project relies on the strategic value of the joint cooperation between the VET system and the production companies to design innovative situated

[1] Other useful resources about the EU policies, strategies or best practices about Green Skills and Work-based learning can be found in the following documentation:
EU competence framework for Green Skills (own initiative opinion);

ETF European Training Foundation study on Work based learning as well as the ETF guide and toolkit publication (2018) named Work based learning: a handbook for policy makers and social partners in ETF countries;

CEDEFOP’s publications Apprentices in Work based learning and The Role of Work based learning in VET and tertiary education learning environments, reproducing and/or virtually simulating the real workplace layout, equipment and organizational roles, to effectively train I-VET, H-VET or C-VET skills about hybrid/electric engines and avionics systems for connected vehicles.

2. Panorama of the green Skills and job profiles within the Automotive Sector

Section A – Desk Analysis of the current skills and job profiles EU frameworks

The variety of the VET qualifications offer at Automotive level across the EU is quite different from a country to another, as it reflects the national prescriptions from the Ministries of Education as well as the demands of the local job market, yet it has converging features when it comes to training programs developing mechanical operations skills as well technical maintenance of the internal combustion vehicle engines (ICE engines).

But as the 21st century dives into the Green & Digital transition, it's harder to imagine which kind of knowledge and skills should I-VET learners acquire, or which upskilling or re-skilling path should workers go through to stay up-to-date in their lifelong professional development.

According to the European Green Deal, alternative fuels and low/zero emission vehicles should reach at least 90% of the total on-road vehicles by 2050. The application of such guidelines takes the EU education and training system to develop job-related skills about hybrid - electric vehicles as well as to electronics circuits supporting assisted and safe drive, thanks to GPS systems and a digital interface for the management of interconnected vehicle fleets as well as human/machine interaction.

A suitable starting point for a VET trainer looking to design a training program to develop e-mobility skills in learners, is looking at 3 frameworks describing the job profiles and qualifications currently existing at EU level:

- The ESCO classification
- The Erasmus+ Sector Skills Alliance DRIVES 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B (Development and Research on Innovative Vocational Education Skills in the Automotive Sector)
- The Sector Skills Alliance ALBATTS 612675-EPP-1-2019-1-SE-EPPKA2-SSA-B (Alliance for battery technology, training and skills for the e-mobility and battery sector)

ESCO is the multilingual classification of European Skills, Competences, and Occupations. The ESCO classification identifies and categorises skills, competences, and occupations relevant for the EU labour market and education and training. Through a filter research, the IG2 partnership selected around 20 job profiles matching the combination of the following keywords:

- Automotive
- Vehicles
- Battery
- Electricity
- Avionics

1. The ESCO Classification
    1.1. After-sales service technician

1.2. Automotive battery technician
1.3. Automotive electrician
1.4. Automotive engineering drafter
1.5. Automotive test driver
1.6. Avionics technician
1.7. Battery assembler
1.8. Battery test technician
1.9. Electrical cable assembler
1.10. Electrical equipment assembler
1.11. Electrical mechanic
1.12. Electrical supervisors
1.13. Electronic equipment assembler
1.14. Fire service vehicle operator
1.15. Mechatronics assembler
1.16. Microelectronics engineering technician
1.17. Motor vehicle assembler
1.18. Motor vehicle mechanics & repairers
1.19. Vehicle electronics installer

For useful reference use, IG2 partnership collected the Job description for each role mentioned above in the IG2 Teaching & Learning Material Folder, available for open & permanent access in a shared repository.

2. The DRIVES Project Job Roles Classification

The Drives Project Sector Skills Alliance, led by the Technical University of Ostrava (Czech Republic), produced standard reference results for a double purpose: on one side, sectorial intelligence needs analysis and a classification of skills and professional qualifications in current and future high demand for the automotive sector; on the other side, an open access e-learning platform (user registration is required) for acquiring micro-credentials in all the knowledge & skills domains that were identified in the sectorial intelligence phase.

Useful reference material from the overall DRIVES project results, available for free download from DRIVES project Results page as well as from IG2 project IO1 Teaching & Learning materials:

2.1. List of Future Job Roles in the Automotive Sector
2.2. Use of the Drives Project Framework Platform: https://drives-compass.eu/home
2.3. Selection of Study Handouts matching IG2 project field of application:
    2.3.1. Drives Project Insights of the Automotive Sector, 2019
    2.3.2. Skills needs and gaps – offer outcomes
    2.3.3. Skills needs and gaps – gaps between "demand" and "offer" outcomes

With the aim at developing and testing VET training programs for the development of Green Skills for the Automotive sector, namely e-mobility and avionics, IG2 partners selected from the Drives Future Job Roles list the most relevant for the sake of the project:

-ADAS/ADF Testing & Validation Engineer

-Sensor Fusion Expert

-Connected Vehicles Technician

-Automotive Cybersecurity Tester

-Rubber Technologist

-Functional Safety Engineer

-Highly Automated Drive Engineer

-Automotive Mechatronics Expert

-Sustainability Expert

-Robotic Technician

- Predictive Maintenance Technician

Note on EQF levels. As the reader can easily note, a number of the Job profiles listed above are about engineering roles, corresponding to EQF 6 University graduate level. As IG2 project is focusing on EQF 3 - 4 - 5 levels, VET trainers should consider the basic and most operative or technical supervisory skills level of any engineering role in order to design training paths suitable for lower qualifications level.

3. The ALBATTS Project Skills Need Analysis in the Battery Sector

Since the European workforce is being highly affected by the change brought about by the transition to electromobility, there will be an increasing need for new training/ reskilling programmes, adapted to the emerging jobs needs, as we further progress to the 2050 EU Green Deal goal of having 90% zero emission vehicle circulating across the EU.

The Alliance for Batteries Technology, Training and Skills (ALBATTS) aims to be a major contribution to the Green mobility in Europe. As the European battery value chain is being developed, organisations from the demand and supply side of skills/competences are brought together, to establish a blueprint for preparedness of future skills across Europe.

ALBATTS project holds a very ambitious purpose to map all the possible fields of application of the battery sector, ranging from mobile to industrial uses, and from road vehicles to aircraft and maritime means of transportation.
The current document will consider only the EV and HEV road vehicles (either cars or trucks), since this is the specific focus of IG2 project.

Useful reference material from the overall ALBATTS project results:

3.1 **Skills Card** to map the required competences and knowledge to operate in the battery sector:
https://www.project-albatts.eu/en/skillscards

3.2 Selection of Study Handouts matching IG2 project field of application:

3.2.1 Report on State of the Art of Job Roles and Education in the sector

3.2.2 Sectoral Skills Intelligence and Strategy for the European Battery Sector 2019-2023

3.3.3 Analysis of Future Needs 2019-2023

The Skills Card set offers a complete overview of the occupational profiles - and corresponding competencies, within the scope of battery manufacturing, e-mobility and stationary battery storage.

ALBATTS addresses both companies and training providers according to the I-VET and C-VET skills development needs, as mapping competencies within job profiles can be useful to:

- create training opportunities [VET]
- improve existing curricula or training programmes [VET providers]
- readjust/improve employee’s selection and recruitment [companies]
- train employees according to the latest sectoral needs [companies]

While the Skills Card ranges through all the different battery application field and levels, for the sake of IG2 project it will be sensible to just focus on VET level job qualifications dealing with automotive sector:

-Automotive Repair and Inspection Personnel
-Battery Manufacturing Technician
-Battery Module Assembly Technician
-Battery Recycling Technician
-Quality Technician

Appendix I (E-mobility Automotive Skills Classification & Glossary) in the present document is providing a list of the Job Roles taken from ESCO framework, DRIVES and ALBATTS project, with the description of the job profiles and skills relevant for the Automotive sector at VET level.

A synoptic comparative view of the three automotive qualification profiles is given below, as a specific interpretation from IG2 partnership.

	DRIVES Development and Research on Innovative Vocational Education Skills	albatts
Motor vehicle assembler		EV Automotive Repair and Inspection Personnel
Automotive Electrician		
Electrical Cable Assembler		
Electrical Equipment Assembler		
Electrical Equipment Inspector		
Electrical Mechanic		
Electrical Supervisor		
Automotive Battery Technician		Battery Manufacturing Technician
Battery Assembler		Battery Module Assembly Technician
Battery Test Technician		Battery Quality Technician
		Battery Recycling Technician
Avionics Technician	ADAS /ADF Testing & Validation Engineer	

	Sensor Fusion Expert	
	Connected Vehicles Technician	
	Automotive Cybersecurity Tester	
	Highly Automated Drive Engineer	
Electronic Equipment Assembler	Automotive Mechatronics Expert	
Electronic Equipment Inspector		
Vehicle Electronics Assembler	Robotic Technician	
	Predictive Maintenance Technician	
Microelectronics Engineering Technician	Functional Safety [Engineer/Technician]	
	Sustainability Manager	
Automotive Engineering Drafter		
Automotive Test Driver		
Fire Service Vehicle Operator		
	Rubber Technologist	
After Sales Service Technician		

4. Further Study Materials available in IG2 Teaching & Learning Materials Folder :
   - HV Regulation: EN 50110-1 Norm and relevant country-level regulations about electrical work
   - ISO/IEC 15504 Information technology – Process assessment, also termed Software Process Improvement and Capability Determination (SPICE) and its application to the automotive sector

Section B. Analysis of the current VET offer at Automotive & E-mobility Level in the IG2 partner countries

The first step for a VET teacher designing an educational path to develop e-mobility skills, either at I-VET or H-VET level, is starting from the learning outcomes that are currently contained in the educational offer. In this way, it's possible to reference Automotive Job Roles & Skills to the actual country-specific VET System in the automotive sector.

The educational scenario at VET level in the automotive sector is quite variable from a country to another: while northern european countries or countries with established practice of dual learning system often include e-mobility in the VET mechanics training courses at all levels, countries with more recent or less structured work-based learning or apprenticeship policies actually foresee e-mobility only at EQF 5 (post-secondary training courses) or EQF 6 (engineering or polytechnics) university courses.

Yet, it is possible to build from scratch a course or modular training units about e-mobility, targeting relevant topics (such as safety rules for HEV/EV management), even if no specific learning objectives are included in the school/training centre programs by the local Ministries of Education.

For example, even if no courses about HEVs/EVs are included in the training offer, VET automotive courses across Europe always include knowledge or practical abilities about electrical mechanics and electronics, or electrical schemes within the vehicle circuits. The following paragraphs will try to highlight any modular unit, knowledge and content matching the e-mobility job-roles and skills that were outlined in the previous chapters, which do have the potential to be exploited as a starting point to trigger e-mobility training.

Where possible and relevant, the present paper will suggest a possible match with the e-mobility job roles identified by the ESCO framework and the Sector Skills Alliances DRIVES & ALBATTS. This will be most significant for the educational offers that are already envisaging e-mobility skills in their curriculum. For those offers which are not yet designed to include HEVs/EVs and /or avionics in the training path, such recommendations will be useful to update their learning program and innovate the didactic methodology as well as the work-based learning environment.

ITALY

As an example for the italian VET offer at automotive level, IG2 project includes two institutions from the Emilia Romagna region, also known as the "Motor Valley" thanks to the establishment of excellence automotive companies such as Ferrari & Maserati in the area of Modena, Ducati and Lamborghini in the area of Bologna, and Dallara in the area of Parma.

IG2 partnership includes an upper secondary VET institution, IIS A. Ferrari, based in Maranello, providing EQF 3 and EQF 4 qualification courses, and a tertiary VET institution, Fondazione ITS Maker Academy, based in Bologna, providing EQF 5 qualification courses.

This chapter offers an overview of the training units, main contents, knowledge and skills of the following courses, selected as the most relevant to start or improve the development of e-mobility training.

- Maintenance and Technical Assistance (EQF 4)
- Technician for the Construction of Transportation Means - Road Vehicles (EQF 4)
- Higher Technician in Hybrid, Electric and Endothermic Engines (EQF 5)
- Higher Technician in Electric & Connected Car and Assisted Driving (EQF 5)

EQF 4 level - VET Secondary Education Diploma

Course Title (1)	**Vocational Course in "Maintenance and Technical Assistance"**
Duration (years)	5
Age of students involved	14-19 years old
EQF Level	4
Hours of frontal classes	Around 400 hours yearly of vocational subjects with 40% time spent in practical laboratories
Hours or practical training (lab)	
Hours or weeks of internships in companies	At least 3 weeks company internship program for each school year

Is it part of a dual learning or apprenticeship program?	No

Within such course, the following contents & learning outcomes are the most appropriate trigger point for initiating a specific training on e-mobility:

- Electrical, mechanical and fluidic components.
- Methods of troubleshooting.
- Operating procedures for disassembly, replacement and reassembly of equipment and facilities.
- Industry diagnostic software.
- Types of faults and how to report, search and diagnose them;
- Sensors and transducers of mechanical process variables;
- Principles of operation and structure of electrical generating and driving machines in direct and alternating current;
- Electrical protection devices, individual and collective;
- Life cycle of an electromechanical, electronic apparatus/plant;
- Techniques and procedures for the assembly and installation of mechanical, electrical and electronic equipment or devices;
- Techniques and procedures for assembling electrical equipment and protection systems;
- Fault diagnosis and intervention procedures;
- Troubleshooting and diagnostic methods;

Such topics can be referenced to the most basic and operative professional levels as outlined in the ESCO classification framework:

- Motor vehicle assembler
- Automotive Electrician
- Electrical Cable Assembler
- Electrical Equipment Assembler
- Electrical Mechanic

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes; Theoretical Knowledge to be gained**	**Learning Outcomes: Practical skills (work-related skills) to be gained**
Technology workshops and exercises	Logical and functional diagrams of equipment and systems. Usage characteristics of **electrical, mechanical and fluidic components.** Techniques for searching, consulting and archiving technical documentation. Functionality of equipment, devices and components of interest. Operating principles of basic instrumentation. Types and characteristics of measuring instruments.	Using, through knowledge and application of safety regulations, specific tools and technologies; Understanding, interpreting and analysing system diagrams; Using the technical documentation required by the regulations to ensure the correct functionality of equipment, installations and technical systems for which it is responsible for maintenance; Identifying the components that make up the system and the various materials used, in order to intervene in the assembly, replacement of components and parts, in accordance with	Producing and interpreting drawings and diagrams of devices and installations of various kinds. Interpreting the operating conditions of installations indicated in diagrams and drawings. **Assembling pneumatic, hydraulic and electrical components** by reading diagrams and drawings. Retrieving, updating and archiving technical documentation of interest. Relating the data in the documentation to the device described. Obtaining information on interventions from the documentation accompanying the machine/plant. Using basic measuring instruments and methods.

		established methods and procedures;	
	Methods of **troubleshooting**. Operating procedures for **disassembly, replacement and reassembly** of equipment and facilities. Prevention and protection criteria relating to the management of operations on equipment and systems of interest. Industry **diagnostic** software. Elements of technical documentation. Plant/machine bill of materials	Correct use of measuring, control and diagnostic instruments, making adjustments to systems and installations; Attention to safety in the living and working environment, protection of the individual, the environment and the territory.	Using, also with computer aids, methods and tools for diagnosing maintenance activities in the sector. **Identifying faults** by applying search methods. **Disassembling, replacing and reassembling components and technological equipment by applying safety procedures.** Drafting technical documentation. Preparing the bill of materials for the elements and equipment making up the system.
Mechanical technologies and applications	Mechanical pneumatic and hydraulic systems; Technical documentation of electromechanical instruments; National, EU and international legislation and regulations on	Using, through knowledge and application of safety regulations, specific tools and technologies; Using the technical documentation required by the regulations to ensure	Identifying and describing the main components of pneumatic and hydraulic circuits of machine tools, systems and mechanical apparatus; Interpreting component data sheets; Applying national and EU regulatory and legislative provisions in the field of health and safety;

	safety, health and accident prevention; Malfunctions and breakdowns of machines and installations as causes of accidents; Individual and collective protective equipment; Rules of conduct to safeguard personal safety and environmental protection in living and working places; Operation of hydraulic and pneumatic circuits; Structure and operation of machine tools, systems and mechanical apparatus; Life cycle of a system, apparatus, plant; **Types of faults and how to report, search and diagnose them;** **Sensors and transducers of mechanical process variables;** Techniques for collecting and analysing operating data;	the correct functionality of equipment, installations and technical systems for which it is responsible for maintenance; Identifying the components that make up the system and the various materials used, in order to intervene in the assembly, replacement of components and parts, in accordance with established methods and procedures; Correct use of measuring, control and diagnostic instruments, make adjustments to systems and installations; Managing the needs of the customer, finding the technical and technological resources to offer services that are effective and economically related to the requirements; Analysing the value, limits and risks of various technical solutions for social and	Identifying hazards and assessing risks in different living and working environments; Using, in operational contexts, methods and tools for control and regulation of mechanical maintenance activities; Analysing installations to diagnose faults; Assessing reliability, availability, maintainability and security of a system at different points in its life cycle; Applying environmental protection regulations; Identifying the structure of plant and machine documents, version management and evolutionary updates in their life cycle.

		cultural life with particular attention to safety in the living and working places, protection of the individual, the environment and the territory.	
Electrical and electronic technologies and applications	Standards for graphic representation of electrical networks and installations; Logical and functional diagrams of equipment, systems and installations; **Principles of operation and structure of electrical generating and driving machines in direct and alternating current;** Structure and components of electrical installations; Technical characteristics of electrical components and apparatus; **Electrical protection devices, individual and collective;** Rules of behaviour in the living and working environment, in normal	Using, through knowledge and application of safety regulations, specific tools and technologies; Using the technical documentation required by the regulations to ensure the correct functionality of equipment, installations and technical systems for which it is responsible for maintenance; Identifying the components that make up the system and the various materials used, in order to intervene in the assembly, replacement of components and parts, in accordance with established methods and procedures;	Interpreting and executing drawings and diagrams of electrical installations; Identifying the elements for protecting the electrical equipment of machines and installations; Identifying the power supply modes and related protections provided; Identifying the electrical characteristics of electrical machines, installations and devices; Using, in operational contexts, methods and measuring instruments specific to electrical and electronic maintenance activities; Using, in operational contexts, control and regulation methods and tools specific to electrical and electronic maintenance activities; Describing the structure and functional organisation of devices and installations subject to maintenance work; Analysing installations to diagnose faults.

	and emergency conditions; **Life cycle of an electromechanical, electronic apparatus/plant;** Types of faults and how to report, search and diagnose them; Sensors and transducers of process variables; Analogue and digital signals, congruent systems; Signal analysis; Techniques for collecting and analysing operating data; Regulations and techniques for decommissioning, recycling and disposal of equipment and processing residues;	Correct use of measuring, control and diagnostic instruments, make adjustments to systems and installations; Managing the customer's needs, finding the technical and technological resources to offer services that are effective and economically related to the requirements; Analysing the value, limits and risks of various technical solutions for social and cultural life with particular attention to safety in the living and working places, protection of the individual, the environment and the territory.	
Installation and maintenance technologies and techniques	Techniques and procedures for the **assembly and installation of mechanical, electrical and electronic equipment or devices;** Techniques and procedures for	Using, through knowledge and application of safety regulations, specific tools and technologies; Using the technical documentation required by the	Interpreting data and technical characteristics of equipment and plant components; Assembling and installing systems, devices and equipment; Observing health and environmental protection regulations during testing, operation and maintenance;

	installing hydraulic and pneumatic circuits; Techniques and procedures for **assembling electrical equipment and protection systems;** Safety and environmental protection regulations; Maintenance levels; Classification of maintenance operations; Operating characteristics and specifications of mechanical, thermal, electrical and electronic machines and systems; **Fault diagnosis and intervention procedures;** **Troubleshooting and diagnostic methods;** Operating procedures for disassembly, replacement and reassembly of equipment and installations; Reliability, Availability, Maintainability and Safety Analysis;	regulations to ensure the correct functionality of equipment, installations and technical systems for which it is responsible for maintenance; Identifying the components that make up the system and the various materials used, in order to intervene in the assembly, replacement of components and parts, in accordance with established methods and procedures; Ensuring and certifying that systems and machines are set up in a workmanlike manner, collaborating in the testing and installation phase; Managing the needs of the customer, finding the technical and technological resources to offer services that are effective and economically related to the requirements; Analysing the value, limits and risks of various technical	Adopting the prevention and protection devices prescribed by the regulations for safety in the working environment; Identifying the criteria for carrying out device tests; Carrying out maintenance work and testing; Searching for and identifying faults; Planning and controlling maintenance work.

	Maintenance Project Guidelines; Techniques for programming maintenance projects.	solutions for social and cultural life with particular attention to safety in the living and working places, personal protection, environment and territory.	

Course Title (2)	**Technical Course in "Construction of the Transportation Means - Road Vehicles**
Duration (years)	5
Age of students involved	14-19 years old
EQF Level	4
Hours of frontal classes	Around 400 hours yearly of vocational subjects with 40% time spent in practical laboratories
Hours or practical training (lab)	
Hours or weeks of internships in companies	At least 3 weeks company internship program for each school year
Is it part of a dual learning or apprenticeship program?	No

Within such course, the following contents & learning outcomes are the most appropriate trigger point for initiating a specific training on e-mobility:

- Diagnostics of on-board electronic equipment;
- Electrical and electronic systems on board, their automatic controls and maintenance;
- Principles of automation and control techniques for on-board equipment, systems and processes.
- Construction, assembly, disassembly and adjustment of structural elements, systems, and connecting elements, according to industry standards;
- Materials for the construction and maintenance of the vehicle**.**

Such topics can be referenced to the technical and supervisory professional levels as outlined in the ESCO classification framework:

- Automotive Electrician
- Electrical Equipment Assembler
- Electrical Equipment Inspector
- Electrical Supervisor
- Electronic Equipment Assembler
- Electronic Equipment Inspector
- Vehicle Electronics Assembler

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes;** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**
Electronics, electrical engineering and automation	Diagnostics of **on-board electronic equipment;** Management systems using software; Process automation and control of the vehicles;	Managing the operation of a specific means of transport and intervening in the design, construction and maintenance of its various components;	Using hardware and software to automate equipment and plants. Interpreting the parameters provided by the integrated navigation system.

	Electrical and electronic systems on board, their automatic controls and maintenance; International conventions and EU and national regulations governing the safety of work, operators, equipment and the environment; **Principles of automation and control techniques for on-board equipment, systems and processes.** Assembly procedures for structural assemblies; Conformation and diagrams of technical installations and their operating parameters; Pump characteristics and operating diagrams. Calculation of pressure losses in installations and sizing of ducts.	Maintaining the means of transport and related facilities; Managing repairs of the different equipment of the vehicle by planning their control and adjustment; Managing activities according to quality system procedures, in compliance with safety regulations; Drafting technical reports and documenting individual and group activities related to professional situations.	Using machines, instruments and specific electrical or electronic equipment and applying the relevant procedures. Programming automation systems. Recognising the different types of process controls implemented with automation systems. Scheduling the maintenance of electromechanical devices. Verifying the operation and characteristics of on-board mechanical assemblies.
Structure, construction, systems and installations of the vehicle - road vehicle	Mechanical, technological and functional characterisation of engineered materials, components and parts; Structural testing, testing and acceptance; Procedures for machining, construction, **assembly, disassembly and adjustment**	Identifying, describing and comparing types and functions of various means and systems of transport; Managing the operation of a specific transportation vehicle and	Analysing energy production and transformation systems related to the means of transport. Identifying and describing the different types of inspection and control used in vehicle maintenance.

	of structural elements, systems, and connecting elements, according to industry standards; Workshop equipment; Maintenance programmes - certification and recommissioning procedures - maintenance inspection/quality control/insurance - interface with vehicle operation - software for analysis and simulation; Basic safety concepts, reading risk analyses, prevention and protection systems, application procedures;	intervening in the design, construction and maintenance of its various components; Maintaining the means of transport and related facilities; Operating and maintaining systems, tools and equipment for loading and unloading passengers and goods, including emergency situations; Managing the repair of the different equipment of the vehicle by planning their control and adjustment; Assessing the environmental impact for proper use of resources and technologies; Managing activities according to quality system procedures, in compliance with safety regulations.	Identifying and applying technical regulations specific to the means of transport. Identifying and applying technologies appropriate to the construction and maintenance needs of components or simple systems. Applying the techniques of production, processing, material treatment and surface coating of vehicles and transport systems. Understanding and applying procedures for the maintenance of the vehicle according to the handbook, even written in English. Performing assembly and disassembly of parts or assemblies of the means of transport. Using the specific terminology of the vehicle by associating it with each of its components and functions. Choosing equipment, tools and different instruments and systems in relation to use. Carrying out simple tests and inspections on structures, materials and components intended for the means of transport.

Mechanics, machines and propulsion systems	Structural elements of the vehicle: types, function and physical characteristics of fluids. Dimensioning and design of organs and apparatuses. **Materials for the construction and maintenance of the vehicle.** Mechanical processing, transformation and coating treatments. Adjustment machine tools and related manuals. Standards and technologies for reducing the environmental impact of means of transport.	Identifying, describing and comparing types and functions of various means and systems of transport; Managing the operation of a specific means of transport and intervening in the design, construction and maintenance of its various components; Maintaining the means of transport and related facilities; Managing the repair of the different equipment of the vehicle by planning the control and adjustment; Managing the activities according to the procedures of the quality system, in compliance with safety regulations; Identifying and applying project management methodologies and techniques.	Applying the principles of mechanics to means of transport. Making design, construction and transformation choices in relation to the materials used in the construction of the means of transport. Analysing energy production and transformation systems related to the means of transport. Understanding and applying the standardised maintenance procedures contained in the vehicle manuals, also in English.

EQF 5 level - Higher Technician Diploma

Both courses, currently provided by the ITS MAKER Academy in Bologna, Italy, provide knowledge and skills about the hybrid and electric engines as well as about the avionics and assisted / autonomous drive systems.

Course Title (3)	**Higher Technician in Hybrid, Electric and Endothermic Engines**
Duration (years)	2
Age of students involved	19-21 years old or older
EQF Level	5
Hours of frontal classes	898
Hours or practical training (lab)	302
Hours or weeks of internships in companies	800
Is it part of a dual learning or apprenticeship programme?	No

Main Modules / Training Units	Teaching/training contents	Learning Outcomes: Theoretical Knowledge to be gained	Learning Outcomes: Practical skills (work-related skills) to be gained
Mechanics applied to traction	Speed, acceleration, forces, torques and kinematics applied to traction (suspension, plungers, steering).	Knowledge of power transmission from engine to road/field	The student must demonstrate recognition of the principles of mechanics applied to traction
Machine construction & FEM	Stresses and deformations in engine organs, fatigue and strength, time-varying loads using FEM methodology.	Finite element analysis of the structural design of an engine.	The student must demonstrate the ability to analyse the structural design of an engine using finite elements.

System & Construction of the Vehicles	Structural calculation and mass distribution; engine, systems, packaging in classical and electrical systems; Technical construction characteristics of endothermic engine components: disassembly operations, analysis and verification of possible wear and tear; Analysis and resolution of mechanical causes of engine malfunction. Reassembly and mechanical and electrical phasing.	Development of the vehicle system by components and integration architecture	The student must demonstrate the ability to configure the development of the vehicle system by components and integration architecture
Dynamic simulation of the vehicle (advanced 3D systems)	Dynamic, directional and stability behaviour; distribution of loads and forces of the vehicle in motion.	3D CAD simulation and validation systems of virtual prototypes of complete vehicles and subsystems.	The student will have to demonstrate the ability to simulate and validate virtual prototypes of complete vehicles and subsystems on 3D CAD.
Electronics, electromagnetism and electrotechnics	Electric and magnetic fields and circuits; electrical energy generation, storage and transformation; power electronics.	The operation of the vehicle's main electrical components	The student must demonstrate the ability to distinguish the operation of the vehicle's main electrical components

Control Units and sensors	Electric propulsion control; endothermic injection and combustion management; hybridisation management for full, minimal, range extender configurations.	Components for electronic motor management in different systems.	The student must demonstrate knowledge of electronic motor management.
ICE engine fundamentals	Otto and Diesel Cycles, Efficiency and Layout, Supercharging	Components, operation and efficiency of an internal combustion engine.	The student must demonstrate the ability to analyse the components, operation and efficiency of an internal combustion engine.

Electric Engines	The laws of electromagnetism; Motor components: stator and rotor; DC motors; Asynchronous induction motors - reluctance motors Synchronous permanent magnet motors: axial flux; radial flux; Characteristics and limitations of electric motors; Functional limits, performance, operating maps and efficiency Mechanical integration: Direct drive; Gearbox. Reversibility under braking and energy generation through kinetic energy recovery.	Basic technical features of electric motors in the vehicle system; The different types of electric traction machines; The basic parameters and characteristics, useful for dimensioning the electric motor.	The student must demonstrate the ability to analyse the basic technical connotation of electric motors in the vehicle system.
Efficiency technologies for electric engines	Injection technologies (direct, water), HCCI ignition, intake and exhaust fluid dynamics, turbocharging; New materials and coatings for engine components;	Emission reduction technologies and engine performance optimisation.	The student will have to demonstrate the ability to apply thermal engine efficiency technologies.

Legislation about engines and emissions	Engine regulations on pollutant emissions: towards the Euro 7 legislative step. Combination of engine control strategies and post-combustion emission abatement systems (particulate filter, AdBlue, catalyst).	Apply European and international exhaust emission control regulations.	The student will have to demonstrate knowledge of exhaust emission control legislation.
Electric Propulsion	Traction system configuration; component control and dimensioning; charging, autonomy and performance	Design and maintenance of electrical traction systems.	The student will have to prove that he/she knows how to design and maintain electrical traction systems.
Hybrid Systems	Types of hybridisation (mild, mini, full, plug-in), configurations, controls and performance; diagnosis of Start&Stop and hybrid systems.	Design and maintenance of hybrid traction systems; applying correct diagnosis methodology of the Start & Stop system and intelligent alternator charging mode.	The student will have to prove that he or she knows how to design and maintain hybrid drive systems.
Automatic Control Technologies and Onboard Avionics	On-board systems for automatic control: telecommunications, data transmission, sensors and cybersecurity.	Perform remote diagnostics on engine behaviour.	The student must demonstrate the ability to perform remote diagnostics on engine behaviour.

Accumulators, storage systems and batteries	Electrochemical storage systems and endothermic engines; accumulators and batteries for traction types. Innovative materials (graphene); Fuel cells. Control and management of storage systems; Thermal control of batteries and temperature timing.	Knowledge of the main construction and performance management solutions for storage systems in different vehicles.	The student will have to demonstrate knowledge of how to manage the performance of storage systems in different vehicles.
Regenerative Recovery of Energy (KERS - HERS)	Kinetic energy recovery systems (KERS) and heat recovery systems (HERS).	Configuration and maintenance of dissipated energy regeneration systems.	The student will have to demonstrate that he/she knows how to set up and maintain regeneration systems for dissipated energy.
System control & diagnostics	Control parameters and performance diagnostics of engines and hybrid systems and their reconfiguration options.	Performance of endothermic engines, electric motors and hybrid systems.	The student will have to demonstrate that he/she can analyse the performance of endothermic engines, electric motors and hybrid systems in order to improve their efficiency.

Engine calibration and propulsion	Configuration of motor control parameters in adaptation to the required ground torque effect.	Knowledge of engine calibration procedures to optimise engine performance.	The student will have to demonstrate that he or she knows how to calibrate the engine to optimise its performance.

Course Title (2)	**Higher Technician in Electric & Connected Car and Assisted Driving**
Duration (years)	2
Age of students involved	19-21 years old or older
EQF Level	5
Hours of frontal classes	662
Hours or practical training (lab)	438
Hours or weeks of internships in companies	800
Is it part of a dual learning or apprenticeship programme?	No

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes;** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**

Reading and interpreting electrical schemes	Parts and assemblies: reading mechanical drawings and electrical and electronic diagrams, with reference also to machining and assembly/installation cycles	Knowledge of machining and assembly cycles based on drawing/technical data.	The student must demonstrate the ability to read and interpret a mechanical technical drawing and an electrical/electronic diagram.
Electronics, electromagnetism and electrotechnics	Electric and magnetic fields and circuits; electrical energy generation, storage and transformation; power electronics	The operation of the vehicle's main electrical components.	The student must demonstrate the ability to distinguish the operation of the vehicle's main electrical components.

Electric Engines	The laws of electromagnetism; Motor components: stator and rotor; DC motors; Asynchronous induction motors - reluctance motors; Synchronous permanent magnet motors: axial flux; radial flux; Characteristics and limitations of electric motors; Functional limits, yields, operating maps and efficiency Mechanical integration: Direct drive; Gearbox. Reversibility during braking and energy generation through kinetic energy recovery.	Basic technical features of electric motors in the vehicle system; The different types of electric traction machines; The basic parameters and characteristics, useful for dimensioning the electric motor;	The student must demonstrate the ability to analyse the basic technical connotation of electric motors in the vehicle system.
Control Units and sensors	Electric propulsion control; endothermic injection and combustion management; hybridisation management for full, minimal, range extender configurations.	Components for electronic motor management in different systems;	The student must demonstrate knowledge of electronic motor management.

System and architecture of vehicles	Structural elements and systems of different vehicle types; Structural calculation and mass distribution; power units, systems, vehicle packaging in hybrid and electric systems; Technical construction characteristics of vehicle systems and their components	Knowledge of the vehicle system in its subsystems and components, with an understanding of the integration architecture.	The student must demonstrate the ability to analyse and understand the vehicle structure by components and integration architecture.
Vehicle construction	Study of the general problems relating to the architecture and components of an electric/hybrid car as a machine, with reference to the main criteria for dimensioning the organs (fatigue, resistance, loads, etc.) and their relations and interactions as a system.	Finite element analysis of the structural design of a hybrid/electric vehicle	The student must demonstrate the ability to analyse the structural design of an electric/hybrid vehicle using finite elements
CAD 3D systems and dynamic simulation of vehicles	Dynamic, directional and stability behaviour; distribution of loads and forces of the vehicle in motion	3D CAD simulation and validation systems of virtual prototypes of complete vehicles and subsystems.	The student will have to demonstrate the ability to simulate and validate virtual prototypes of complete vehicles and subsystems on 3D CAD.

ICE engine fundamentals	Otto and Diesel Cycles, Efficiency and Layout, Supercharging.	Components, operation and efficiency of an internal combustion engine.	The student must demonstrate the ability to analyse the components, operation and efficiency of an internal combustion engine.
Powertrain traction systems	Structure, characteristics, performance of electric and hybrid propulsion systems; speed, acceleration, forces, torques and kinematics applied to traction.	Power transmission from powertrain to road/field.	The learner must demonstrate recognition of the dynamics of electric and hybrid powertrains applied to traction issues.

Onboard Infotainment	On-board computers, infotainment systems and components, operating systems and sw, integration with external operating systems (smartphones and mobile devices). HMI: Human Machine Interface; Body Pc and vehicle control units and their integration into Body Electronics and its systems and components; Infotainment systems; integration with mobile systems and smartphones (Apple, Android); Bluetooth connections and vehicle function control via app; Satellite systems, GPS, localisation and security	The main functions of on-board infotelematics technologies, with particular reference to related systems.	The student will have to demonstrate the ability to configure and maintain vehicle infotainment and connectivity systems

CAN networks and vehicle system communication	KWP2000, LIN, CAN networks, CAN FD, Flex Ray, secure gateway, OTA: basic principles, evolution, interfacing strategies and architectures; CAN networks: HW and SW architecture, communication protocols; Low and high-speed CAN networks; Instrumentation and measurement SW; CAN networks instrumentation and measurement SW: use of instrumentation and vehicle interfacing; measurements and signal interpretation, troubleshooting, basic electrical measurements.	Evolution in data communication between vehicle nodes; Main communication protocols (CAN focus); Practical use of CAN network analysers on the market, recording, analysis, fault simulation.	The student must demonstrate knowledge of data acquisition protocols, instrumentation and techniques and analysis SW configurations.
Legislation about engines and emissions	Engine regulations on pollutant emissions: towards the Euro 7 legislative step; Combination of engine control strategies and post-combustion emission abatement systems (particulate filter, AdBlue, catalyst).	Apply European and international exhaust emission control regulations.	The student must demonstrate knowledge of exhaust emission control legislation.

Electric propulsion	Traction system configuration; component control and dimensioning; charging, autonomy and performance.	Design and maintenance of electrical traction systems.	The student will have to prove that he/she knows how to design and maintain electrical traction systems.
Hybrid Systems	Types of hybridisation (mild, mini, full, plug-in), configurations, controls and performance; diagnosis of Start&Stop and hybrid systems.	Design and maintenance of hybrid traction systems; applying correct diagnosis methodology of the Start & Stop system and intelligent alternator charging mode.	The student will have to demonstrate the ability to design and maintain hybrid drive systems.
Accumulators, storage systems and batteries	Electrochemical storage systems and endothermic engines; accumulators and batteries for traction types. Innovative materials (graphene). Fuel cells. Control and management of storage systems. Thermal control of batteries and temperature timing.	Knowledge of the main construction and performance management solutions for storage systems in different vehicles	The student will have to demonstrate knowledge of how to manage the performance of storage systems in different vehicles.

Regenerative Recovery of Energy (KERS - HERS)	Kinetic energy recovery systems (KERS) and heat recovery systems (HERS)	Configuration and maintenance of dissipated energy regeneration systems	The student will have to demonstrate that he/she knows how to set up and maintain regeneration systems for dissipated energy.
ADAS systems	Driver assistance systems: HW, SW, functionality, integration, redundancy; Main technologies: ABS/ESP, Radar, Cameras, Airbar, parking sensors, Lidar - fusion, servo electric; Safety, comfort and assisted driving functions: speed control, parking and lane change, emergency braking, lane detection and line assist, adaptive lighting and night vision; Functional safety and related regulations. Diagnosis, troubleshooting, analysis of acquired data and use of technical documentation.	Basic characteristics and functionality of sensors, actuators and vehicle nodes. Acquire theoretical and practical knowledge, positions and assembly specifications of the main components. Managing technical documentation and data acquired for diagnosis and control activities.	The student will have to demonstrate knowledge of ADAS, autonomous driving levels and carry out practical procedures on diagnosis/fault finding and calibration.

System diagnostics	Control parameters and performance diagnostics of engines and hybrid systems and their reconfiguration options.	Performance of endothermic engines, electric motors and hybrid systems.	The student will have to demonstrate the ability to analyse the performance of endothermic engines, electric motors and hybrid systems in order to make them more efficient.

NETHERLANDS

All the courses listed below, currently jointly provided by the ROC MIDDEN NEDERLAND - Automotive College, Utrecht, and INNOVAM Nieuwegein, Netherlands, provide knowledge and skills about the hybrid and electric engines as well as about the avionics and assisted / autonomous drive systems.

The following courses provide VET secondary education at automotive level:

First Car Technician (EQF 3)

First Truck Technician (EQF 3)

Technical Specialist Car Technology (EQF 4)

Technical Specialist Truck Technology (EQF 4)

Course Title (1)	**First Car Technician** **First Truck Technician**
Duration (years)	3 years
Age of students involved	16+ years
EQF Level	Level 3

Hours of theoretical study	4 hours per week
Hours or practical training (lab)	4 hours per week
Hours or weeks of internships in companies	2x 8 hours per week
Is it part of a dual learning or apprenticeship program?	Yes

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes;** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**

Co-funded by the Erasmus+ Programme of the European Union

Hybrid and electrical drivetrain	Introduction to hybrid and electrical drivetrain Energy streams in hybrid vehicles Electric drive Continuous Variable Transmission Single planetary gear train Transmission ratios Hybrid vehicles with planetary gear train Towing of hybrid vehicles met planetary gear train Recognising different kinds of drive Case study: hybrid and electric drive trains.	Energy streams in hybrid vehicles. Working on Hybrid vehicles Working on EV Theory of ensuring tension-free situation Students can transfer calculations to real measurements and interpret them.	Students are able to recognise Hybrid and EV vehicles name different components. Students can make a hybrid and EV tension-free in a safe manner Students can evaluate and analyze a battery management system

NEN9140 (VOP)	Working with tension Working on hybrid & electric vehicles HV-vehicles in the workshop Persons (who is allowed to do what on (H)EV-vehicles) Different working working procedures HV-vehicles (VOP) Switching of HV-system to tension-free(NEN) Safeguarding and responsibilities NEN9140 Case study: written instruction NEN9140	Working safely with and on EV. Theory of making it tension-free. Students can calculate the charging level on the basis of the theory and evaluate it by the workshop data.	Students learn how to work with different types of electric motors. Students can identify and name the different drive trains and recognise and name the important differences.
Charging system	HV battery Charging plug Charging lead Charging Case study: charging system	Structure of a HV battery and its charging mechanisms	Safely operate the charging procedures of an HV battery

Electric engines	Rotation field Synchronous three-phase current motor with permanent magnet Resolver Short-circuit anchor motor Case study: Electric motors.	Structure of an electric engine	Students can recognize and name the different components of an electric engine and identify the phases of the working mechanism
Inverter/converter battery management	DC/DC inverter Battery Management System Battery balancing Temperature regulation HV battery	Structure of a HV battery	Students can recognize and name the different components of a HV battery and identify the phases of the working mechanism

Course Title (2)	**Technical Specialist Car Technology** **Technical Specialist Truck Technology**
Duration (years)	4 years
Age of students involved	16+ years
EQF Level	Level 4
Hours of theoretical study	4 hours per week
Hours or practical training (lab)	4 hours per week
Hours or weeks of internships in companies	2x 8 hours per week
Is it part of a dual learning or apprenticeship program?	Yes

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes:** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**
Hybrid and electric drive train	Energy streams in hybrid vehicles Electric drive Hybrid vehicles met planetary gear train.	Energy streams in hybrid vehicles. Working on Hybrid vehicles Working theory of making EV tension-free Students can calculate the charging level on the basis of the theory and evaluate it by the workshop data	Students can identify and name the different drive trains and recognise and name the main differences. Students can make a hybrid and EV current-free in a safe manner Students can evaluate and analyze battery management system

Hybrid and electric drive train	Introductory workshop to H(EV)-vehicles Person (who is allowed to do what on (H)EV-vehicles) Protocols Safeguarding and responsibilities Working with tension Working on hybrid vehicles Recognising drive trains Tension-free shifting of HV system Case study: NEN 9140 in the workshop	Working safely with hands on EV. Theory of making tension-free. Students can calculate the charging level on the basis of the theory and evaluate it by the workshop data.	Students learn to work with different kinds of electric motors. Students can identify and name the different drive trains and recognise and name the main differences.
Charging system	HV battery Static check of digital sensors Charging plug Charging lead Charging protocol Case study: charging system.	Structure of a HV battery and its charging mechanisms	Safely operate the charging procedures of an HV battery

Electric motors	Rotation field Synchronous three-phase current motor with permanent magnet Resolver Short-circuit anchor motor Case Study: Electric motors	Structure of an electric engine	Students can recognize and name the different components of an electric engine and identify the phases of the working mechanism
Inverter/converter **battery management**	DC/DC inverter Inverter Battery Management System State of charge Balancing of battery Temperature regulation of HV battery Programme of temperature regulation of HV battery Case study: inverter/converter and Battery Management.	Structure of a HV battery	Students can recognize and name the different components of a HV battery and identify the phases of the working mechanism

Short Modular Courses on e-vehicles, suitable for I-VET and C-VET training as well, are also offered by the Dutch partners, and are mostly attended by workers currently employed in the automotive workshops and companies in the whole country**:**

Course Title (1)	**Safe working on e-vehicles basics**
Duration	1 day (8 hours)
Age of participants involved	18+
EQF Level	2
Hours of theoretical study	2 (online course)
Hours or practical training (lab)	6
Hours or weeks of internships in companies	none
Is it part of a dual learning or apprenticeship program?	Dual (online and face to face)

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes:** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**
Online module	Safety risks Safety Measures Personal Protection Electrical components Disconnect HV-system	Have knowledge about safety procedures for working on HV-systems	
Face to face module	Safety risks Safety Measures Personal Protection Electrical components Disconnect HV-system		Able to follow safety procedures for working on HV-systems. Able to recognize the different HV-components.

Course Title (2)	**Safe working on e-vehicles advanced**
Duration	1 day (8 hours)
Age of participants involved	18+
EQF Level	3

Hours of theoretical study	2 (online course)
Hours or practical training (lab)	6
Hours or weeks of internships in companies	none
Is it part of a dual learning or apprenticeship program?	Dual (online and face to face)

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes:** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**
Online module	Working of Electrical components Procedures to Disconnect HV-system according to manufacturers Hybrid systems E-Brake systems Basics diagnosis of HV-systems	How HV-components work Knowledge of different procedures to disconnect HV-systems Knowledge of regenerative braking works	Able to follow safety procedures for working on HV-systems. Able to perform basic diagnostics on HV-systems.

Face to face module	Working of Electrical components Procedures to Disconnect HV-system according to manufacturers Hybrid systems E-Brake systems Basics diagnosis of HV-systems		

Course Title (3)	**Maintenance and repair of e-vehicles (battery)**
Duration	1 day (8 hours)
Age of participants involved	18+
EQF Level	3
Hours of theoretical study	2 (online course)
Hours or practical training (lab)	6
Hours or weeks of internships in companies	none
Is it part of a dual learning or apprenticeship program?	Dual (online and face to face)

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes;** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**
Online module	HV-battery build-up Battery cells (Ni-Mh, Li-ion) HV-relays, contactors Temperature management Battery charging Charging strategies Safety procedures for working on HV-batteries	Ability to recognize different HV-batteries Knowledge of the different parts that build up an HV-battery pack Knowledge of the safety procedures	Ability to follow safety procedures for working on HV-batteries. Ability to perform maintenance and basic repairs on HV-batteries.
Face to face module	HV-battery build-up Battery cells (Ni-Mh, Li-ion) HV-relays, contactors Temperature management Battery charging Charging strategies Safety procedures for working on HV-batteries		

Course Title (4)	**Diagnosis on e-vehicles (battery)**
Duration	1 day (8 hours)
Age of participants involved	18+
EQF Level	4
Hours of theoretical study	2 (online course)
Hours or practical training (lab)	6
Hours or weeks of internships in companies	none
Is it part of a dual learning or apprenticeship program?	Dual (online and face to face)

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes;** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**

Online module	How to perform diagnosis on HV-battery systems How to set-up a diagnosis plan Battery management systems Charging systems	Ability to recognize different HV-batteries Knowledge of the different parts that build up an HV-battery pack Knowledge of the safety procedures	Ability to diagnose HV-battery management systems. Ability to diagnose charging systems.
Face to face module	Performing diagnosis on HV-battery systems Setting-up a diagnosis plan Battery management system diagnosis Diagnosis of Charging systems		

Course Title (5)	**Maintenance and repair of e-vehicles (drive line)**
Duration	1 day (8 hours)
Age of participants involved	18+
EQF Level	3
Hours of theoretical study	2 (online course)
Hours or practical training (lab)	6

Hours or weeks of internships in companies	none
Is it part of a dual learning or apprenticeship program?	Dual (online and face to face)

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes:** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**
Online module	Electric motors (AC, DC, Brushless) Engine controls Regenerative braking 2-wheel drive, 4-wheel drive systems Safety procedures	Ability to recognize different types of electric motors Know the different parts of electric drive systems Know how regenerative braking works.	Ability to recognize all types of electric motors Ability to understand data form the engine management control module

Face to face module	Electric motors (AC, DC, Brushless) Engine controls Regenerative braking 2-wheel drive, 4-wheel drive systems Safety procedures		Ability to make basic repairs on e-drive systems

Course Title (6)	Diagnosis of e-vehicles (drive line)
Duration	1 day (8 hours)
Age of participants involved	18+
EQF Level	4
Hours of theoretical study	2 (online course)
Hours or practical training (lab)	6
Hours or weeks of internships in companies	none
Is it part of a dual learning or apprenticeship program?	Dual (online and face to face)

<table>
<tr><th>Main Modules / Training Units</th><th>Teaching/training contents</th><th>Learning Outcomes:

Theoretical Knowledge to be gained</th><th>Learning Outcomes:

Practical skills (work-related skills) to be gained</th></tr>
<tr><td>Online module</td><td>How to perform diagnosis on electric motors

How to perform diagnosis on HV-drive systems

How to set-up a diagnosis plan

How to recognize drive line failures

Safety procedures</td><td rowspan="2">Ability to recognize different types of failure of electric motors and drive lines

Ability to set-up a diagnosis plan</td><td rowspan="2">Ability to perform diagnosis on electric motors and drive lines

Ability to work with a diagnosis plan

Ability to diagnose drive line failures</td></tr>
<tr><td>Face to face module</td><td>Performing diagnosis on electric motors

Performing diagnosis on HV-drive systems

Setting-up a diagnosis plan

Diagnosis of drive line failures

Safety procedures</td></tr>
</table>

LITHUANIA

To provide evidence of the **Lithuanian** context at VET secondary education at automotive level, this paper reports two study courses currently provided at the Car Mechanic High School based in the capital city Vilnius. At VAVM - Vilniaus Automechanikos ir Verslo Mokykla there are two main specialization running on:

-Automotive Mechanic (EQF 4)

-Automotive Electric Equipment Repairer (EQF 4)

Courses do not currently provide a specialisation in HEVs/EVs or avionics circuits, yet work-based training also include maintenance and diagnostics operations on hybrid or electric vehicles. Training modules include contents, knowledge and skills suitable to become the starting point which further e-mobility training can be based upon. Such topics include the following modules:

-Engines technical maintenance

-Transmission technical maintenance

-Automobile electrical equipment repair

-Engines electrical equipment

-Transmission electrical equipment

-Automobile comfort and safety electrical equipment

Such topics can be referenced to the most operative professional levels as outlined in the ESCO classification framework:

- Motor vehicle assembler
- Automotive Electrician
- Electrical Cable Assembler
- Electrical Equipment Assembler
- Electrical Mechanic

Course Title (1)	**Automotive Mechanic**
Duration (years)	3
Age of students involved	17<

EQF Level	4
Hours of theoretical study	About 40% of all time
Hours or practical training (lab)	About 60% of all time
Hours or weeks of internships in companies	11 weeks of short time internships and one long term 600 hour internship at the end of the program.
Is it part of a dual learning or apprenticeship program?	Dual learning program, with an ability of apprenticeship.

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes:** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**
Introduction into profession	Work safety; Introduction into business;	Basic business knowledge, professional responsibility.	Ability to interact with people, to use and maintain technological equipment, understanding professional responsibility.
Metal technological works	Metal processing technologies; Materials;	Technology of metal processing	Technical measurements, drawings, metal welding, soldering cutting

	Technological equipment.		
Engines technical maintenance	Engine components; Adjustments; Repair techniques; Ecological issues.	Engine components, work principles, repair techniques.	Ability to choose materials for maintenance, repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.
Otto engines technical maintenance	Otto engine components; Adjustments; Sensors; control units; control principles; repair techniques; ecological issues.	Ignition and fuel system components, work principles, sensors, control units, control principles, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.

Diesel engines technical maintenance	Diesel engine components; Adjustments; Control principles; Repair techniques; Ecological issues.	Diesel injection system components, work principles, control principles, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.
Transmission technical maintenance	Transmission components; Adjustments; repair techniques;	Transmission, gearbox components, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.
Chassis technical maintenance	Chassis components; Adjustments; Repair techniques;	Chassis and brake system components, work principles, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.

Automobile electrical equipment repair	Basic electronic knowledge; Electronics principles; Electronic components; Repair of electronic devices.	Basic electronics knowledge, Basic laws of physics, electric induction, Ohms law, electronic components and work principles, electrical wiring and its diagrams.	Ability to connect electrical wirings, diagnose electronic malfunctions, replacement of electronic components, repair of components.
Additional modules: Driving; Body diagnostics and repair.	Driving motor vehicles; Road safety; Body repair technology; Body maintenance; Body repair materials.	Road traffic regulations; First aid in accidents; Body components; Body maintenance technology; Repair technology.	Driving of motor vehicles, Choosing right materials for body maintenance; Choosing right materials for body repair; Body repair.

Course Title (2)	**Automobile Electric Equipment Repairer**
Duration (years)	3
Age of students involved	17<
EQF Level	4
Hours of theoretical study	About 40% of all time

Hours or practical training (lab)	About 60% of all time
Hours or weeks of internships in companies	11 weeks of short time internships and one long term 600 hour internship at the end of the program.
Is it part of a dual learning or apprenticeship program?	Dual learning program, with an ability of apprenticeship.

Main Modules / Training Units	**Teaching/training contents**	**Learning Outcomes;** **Theoretical Knowledge to be gained**	**Learning Outcomes:** **Practical skills (work-related skills) to be gained**
Introduction into profession	Work safety; Introduction into business.	Basic business knowledge, professional responsibility.	Ability to interact with people, to use and maintain technological equipment, understanding professional responsibility.
Metal technological works	Metal processing technologies; Materials; Technological equipment.	Technology of metal processing	Technical measurements, drawings, metal welding, soldering cutting

Engines electrical equipment	Engine components; sensors; Control units; Control principles; Repair techniques; Ecological issues.	Engine components, work principles, sensors, control units, control principles, repair techniques.	Ability to choose materials for maintenance, repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.
Otto engines electrical equipment	Otto engine components; sensors; Control units; Control principles; Repair techniques; Ecological issues.	Ignition and fuel system components, work principles, sensors, control units, control principles, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.
Diesel engines electrical equipment	Diesel engine components; sensors; Control units; Control principles; Repair techniques; Ecological issues.	Diesel injection system components, work principles, sensors, control units, control principles, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.

Transmission electrical equipment	Transmission components; Sensors; Control units; Control principles; Repair techniques;	Transmission, gearbox components, work principles, sensors, control units, control principles, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.
Chassis electrical equipment	Chassis components; sensors; Control units; Control principles; Repair techniques;	Chassis and brake system components, work principles, sensors, control units, control principles, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.
Automobile electrical equipment repair	Basic electronic knowledge; Electronics principles; Electronic components; Repair of electronic devices.	Basic electronics knowledge, Basic laws of physics, electric induction, Ohms law, electronic components and work principles, electrical wiring and its diagrams.	Ability to connect electrical wirings, diagnose electronic malfunctions, replacement of electronic components, repair of components.

Automobile comfort and safety electrical equipment	Comfort and safety components; Sensors; Control units; Control principles; Repair techniques;	Comfort and safety system components, work principles, sensors, control units, control principles, repair techniques.	Repair techniques, technical maintenance, repair, diagnosing malfunctioning components, adaptation and regulation of components.
Additional modules: Driving; Body diagnostics and repair.	Driving motor vehicles; Road safety; Body repair technology; Body maintenance; Body repair materials.	Road traffic regulations; First aid in accidents; Body components; Body maintenance technology; Repair technology.	Driving of motor vehicles, Choosing right materials for body maintenance; Choosing right materials for body repair; Body repair.

SWEDEN

To portray the Swedish context at VET secondary level in the automotive sector, the present paper will illustrate the public-private cooperation formula represented by Göteborgs Tekniska College, Göteborg, which is a partner of IG2 project together with Volvo Trucks company.

Gothenburg Technical College is an educational and training institution co-owned by Volvo Group, Volvo Cars and the City of Gothenburg.

The institution offers industrial technical training adapted to the needs of the market, providing upper secondary education (EQF 4), vocational higher education courses in applied sciences (EQF 5) as well as company training courses (C-VET). The learning centres are centrally located in Gothenburg in the vibrant Lindholmen city quarter and in the middle of the business district at Volvo Torslanda.

As Volvo Group made a strategic asset out of e-mobility, through the production and commercialization of e-trucks fleet by Volvo Lastvagnar AB, teachers at GTC developed a learning suite about Electro-mobility, designed and taught by trainers with direct experience from the manufacturing and corporate market.

The E-mobility training suite is composed of the following modules, which are in turn included in the qualification or market courses offered at GTC:

Module Title	Duration	Contents
EV Awareness	4 hours (theory)	• Environmental Issues & Constraints • Market development • Total cost of ownership • Technology involved
Battery System Overview	8 hours (theory and practice)	• Battery Technology • Electric Safety • Battery Management • Usage • Durability
Lithium-Ion battery system	16 hours (theory and practice)	• Cell Formats • Physical Chemistry • Supply Chain • System Design • Production
EV charging and power supply	12 hours (theory and practice)	• Modes • Behaviour • Infrastructure • Business Model • Power Components

Electrical machines and transmission	16 hours (theory and practice)	• Drives overview • Hybrid powertrain typologies • Circuit theory

As part of the upper secondary level courses, GTC offers an indentation of the Technical Program plus and indentation of the Industrial Program, both of them including and extending the core modules of the e-mobility suite:

Maintenance Technician – Automation (EQF 4)	Maintenance Technician – Electrical Mechanics (EQF 4)
Robotics Electric Power Technology Applied Automation Technology Industrial Automation Technology	Production Equipment Electric Motor Control Remedial Maintenance

GTC also offers Lifelong training courses about E-mobility for workers and companies (C-VET) in more areas:

Area of "Electric Vehicles and Battery Technology"

Area "Electrical Safety"

Courses have a duration from 4 to 50 hours and are taught partly onsite and partly online. All of them have a modular structure that can build up with other short courses from the catalogue. The main modules are:

- Battery System Lithium-Ion
- Battery System Overview
- Battery Management Connection and Control
- Battery Management Systems
- Battery Technician
- Battery Testing
- Digital Technology Vehicles
- E-vehicles: design and function
- Electric Machines and transmission
- Electric vehicle safety
- Sustainable transport systems

GTC also established an open digital reference library for electro-mobility, meant as an ever-growing archive about electric vehicles, power supply, charging, power storage, sustainable energy system and environmental issues, counting more than 7 thousands resources today.

3. Co-designing the Innovation Garage of Garages

First of all, it's important to explain what do we mean by the term "Innovation Garage".

In this specific project's context, we mean "Innovation Garage" as the process of **bringing together VET Providers and companies** from the **automotive sector** (here referred to as "garage"), to **co-design** both the **training workplace** and the **learning path** for the development of **green mobility skills** at multiple **VET** levels, from I-VET to H-VET to C-VET.

As this is a strategic partnership for cooperation, IG2 project's goal is not about technological innovation in the automotive field, but it's about **innovating** the training **methodology** and the design of the **learning environment**.

Where does it come from? We are borrowing the term from IBM Garage Field Guide, where it stands for an participative and co-operative framework to invite, facilitate and boost innovation and knowledge management from a bottom-up perspective.

By bringing together stakeholders involved in the automotive sector, both at VET system, at teachers/trainers level, at student level and at company level, IG2 project strives to make cooperation happen to co-design learning paths for the green mobility revolution. Co-creation is not just about training programs and skills/qualification frameworks, but it's about the workplace layout as well. The training setting is meant as a situated environment where VET learners and scaffolders from the business world co-execute operations and co-enact organisational roles similar to the real workplace.

In the automotive sector, the Innovation Garage approach was adopted by Thyssenkrupp Group too, as a way to reach a higher level of innovation within the mobility sector. In the corporate mindset, innovation can be created not just by R&D department and shared top-down, but small start-ups among technicians, managers, customers and investors too can be set up to co-design &co-create new product prototypes and processes.

2-Study Materials

In the Teaching & Learning material collection put together by the IG2 project, partners produced contributions to guide VET trainers as well as workshops managers, through the changes affecting the mechanical garages and their evolution from the 2020s up until the 2040s or 2050, which is the ultimate horizon of the European Green Deal scenario about the European Union becoming a zero emission and carbon neutral area. The following documents and presentations, available for free download and consultation under the Creative Common 4.0 Share Alike licence, also cover the development of future automotive workers' skills for a smooth transition towards the job market, as well as the needs analysis of the automotive sector in terms of current gaps generated by the quick evolution of the EVs (electric vehicles), HEV (hybrid electric vehicles), of the digital softwares managing the Autonomous and Assisted Drive systems (ADAS) as well as the remote or in-cloud predictive maintenance (OTA - over the air assistance).

Please find below the list of documents providing scenarios, sets of knowledges and skills as well as instructions about how to configure the layout of an effective training workplace for the development of e-mobility skills at VET level:

- The Workshop of the Future – by Innovam (first published in 2018)
- E-Mobility and Education – Needs Analysis by Innovam
- E-Mobility and Education – Needs Analysis by Zener Italia
- E-Mobility and Education – Needs Analysis by Moller Auto, Lithuania

According to Innovam's analysis, a few drivers of change are affecting the automotive sector at EU and global level, namely:

-the legislation at national and international level, as well as the regulations established by the local Ministries of Transportation

- the rise of Electric Vehicle (EV) technology

-the rise of digital and remote maintenance (OTA - over the air assistance)

-the rise of autonomous and assisted drive systems (ADAS), thanks to the digital and software technology

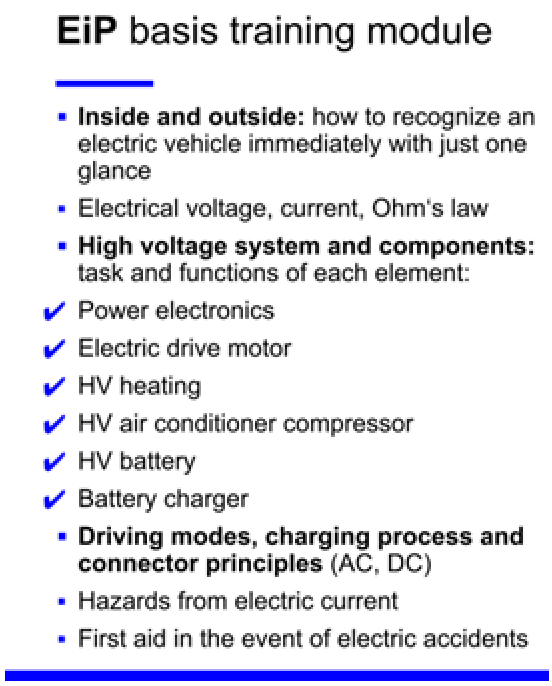
Nonetheless, such four drivers of change are not independently transforming the automotive system but their impact is closely tied to how responsive consumers will be towards such changes in the market. When legislation is not pushing forward towards electrification, and customers are not much interested in choosing connected cars or there are less entrants in the market overall, by 2040 there will be a limited number of drivers releasing real-time data for remote maintenance, and the EV as well as the autonomous drive market will shrink. Since new technologies are not hugely impacting the sector, ICE (internal combustion engines) vehicles will amount to around 70% and traditional mechanics will be still prevailing in workshops, with just a -15%/-20% drop compared to 2020. Pool cars are not widely spread, yet they are common just in bigger cities and MaaS (mobility as a service) is not a big trend.

Since the European parliament decreed in late 2022 that by 2035 no more ICE vehicles should be produced and sold across the EU, such conservative scenario does not seem to be happening though, as consumers will be forced either to own a hybrid or electric car, or to go for car pooling services.

Such recent evolution, occurred after the first release of "The Workshop of the Future" paper (2018), makes an alternative, more progressive overall picture closer, where EVs are spread nationwide over 70% of the total vehicles, connected cars and pooled cars are widely used by the majority of citizens as daily means of transportation within the MaaS scenario, and OTA (over the air) maintenance is regularly performed by a vast number of providers. As this hypothesis is coming true, the organisation of workshops/garages and the traditional role of ICE fitters will be deeply affected, with an estimate of -40% workshop staff needed and traditional mechanics less and less involved in the maintenance operations, which will rather be mostly remote software update.

So, how such changes will mostly affect the training and skills of the staff within the Automotive workshop?

According to Moller Auto - Lithuania, official Volkswagen and Audi dealer, as HEVs and EVs become more and more common, it is vital that all the workers in the workshops are trained as EiP - electrically instructed persons, even while performing basic maintenance or repair operations. On top of that, a smaller number of staff shall be HVTs - high voltage technicians, responsible of de-energising the HV batteries and of the general start-up of an HEV or EV. Only a restricted number of people, fully qualified as HVE - high voltage expert, are allowed to manage high voltage batteries and to activate or deactivate high voltage systems by all means.



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The layout and equipment of an automotive workshop where HEVs and EVs are maintained should always bear warning and danger signs about high voltage circuits over the place:

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Workplace: how to identify high-voltage components?

There are various high-voltage marking around a high-voltage vehicle. These markers indicate that hazards due to electric current can be expected on this vehicle:

- Yellow and black barricade tape
- Warning signs and prohibition signs around and on the vehicle
- Warning signs and prohibition signs on components in the vehicle
- Orange wires and components

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Special tools and recommended accessories to be found in the automotive workshop for HEV / HV vehicle maintenance, and useful tools for the VET students' training workplace too:

High-voltage diagnosis box VAS 5581

Using the high-voltage diagnosis box VAS 5581, you can check the high-voltage traction batteries of hybrid, plug-in hybrid and electric vehicles of the Volkswagen Group quickly and easily.
In doing so, the diagnosis box is connected directly to the control unit of the high-voltage battery using the adapter cable, either in the vehicle or once removed, to read off the measured values, e.g. the voltage of the individual modules. To connect with the diagnosis unit that reads out the measured values, the diagnosis interface VAS 6154 is connected directly to the diagnosis box. A defective module can, thus, be found quickly and the repair can take place. The diagnosis box is supplied with voltage via a power pack or a separate accumulator.

Scope of delivery	Recommended accessories
1× high-voltage diagnosis box	+ Different adapter cables VAS 5581/XX (various ASE numbers)
1× adapter cable	+ Accumulator VAS 5581/10 (ASE 109 051 00 000)
1× power pack	

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"Premium" diagnosis unit VAS 6160E

The "Premium" diagnosis unit VAS 6160E with touchscreen embodies the latest generation of diagnosis units. With the special Windows 10 version IoT Enterprise LTSB as its basis, it offers maximum operating comfort and the highest possible operator safety.

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Isolator box, 198-pin VAS 6606

The isolator box VAS 6606 is used for the diagnosis on control devices with 198-pin connections that are being used in the Group since 2010. It has a modular design and is equipped with 66 connections per module.
Adapter cables already present from the V.A.G 1598 series can be used with these modules, with an adapter in some cases. The adapter cables are available as an accessory. The isolator box is voltage safe up to 60 V to ensure that systems from the high-voltage range are sufficiently protected.

Scope of delivery

- 1 × isolator box module 1 (coding A+B) with connecting bridges and templates
- 1 × isolator box module 2 (coding C+D) with connecting bridges and templates
- 1 × isolator box module 3 (coding E+F) with connecting bridges and templates
- 2 × test adapters
- 1 × earth cable
- 1 × transport box

Recommended accessories

+ Test adapter VAS 6606/XX (various ASE numbers)

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Scissor-type assembly platform VAS 6131B

With the scissor-type assembly platform VAS 6131B, engines and gearboxes of the modern power unit generation can be installed and removed as a unit quickly and without additional tools. This power unit assembly has a weight of approx. 800 kg, which means that the standard engine and gearbox jack cannot be used. Operating comfort and simple manoeuvrability set benchmarks and make the product indispensable.

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High-voltage tool set VAS 6762

Comprehensive tool set with insulated tools for high-voltage experts.

Scope of delivery

- 10 × screwdrivers
- 15 × hexagon socket sets
- 3 × screwdriver bits
- 1 × reversible ratchet ⅜"
- 2 × extensions ⅜" (74 mm/126 mm)
- 4 × pliers (universal, flat, nose and combination pliers)
- 1 × side cutter
- 1 × wire cutter
- 1 × cutting knife with insulation
- 1 × voltage tester
- 2 × set each with 5 end caps 1000 V (Ø 30 mm and Ø 40 mm)
- 2 × warning signs ("Dangerous electric voltage" and "Switching prohibited")
- 1 × film barrier tape
- 1 × tool case
- 1 × insulation mat in bag
- 1 × release tool T40258

Recommended accessories

- + Hexagon socket, 10 mm VAS 6762/46 (ASE 447 115 00 000)
- + End caps VAS 6762/47 (ASE 317 003 00 000)
- + End caps VAS 6762/48 (ASE 317 004 00 000)

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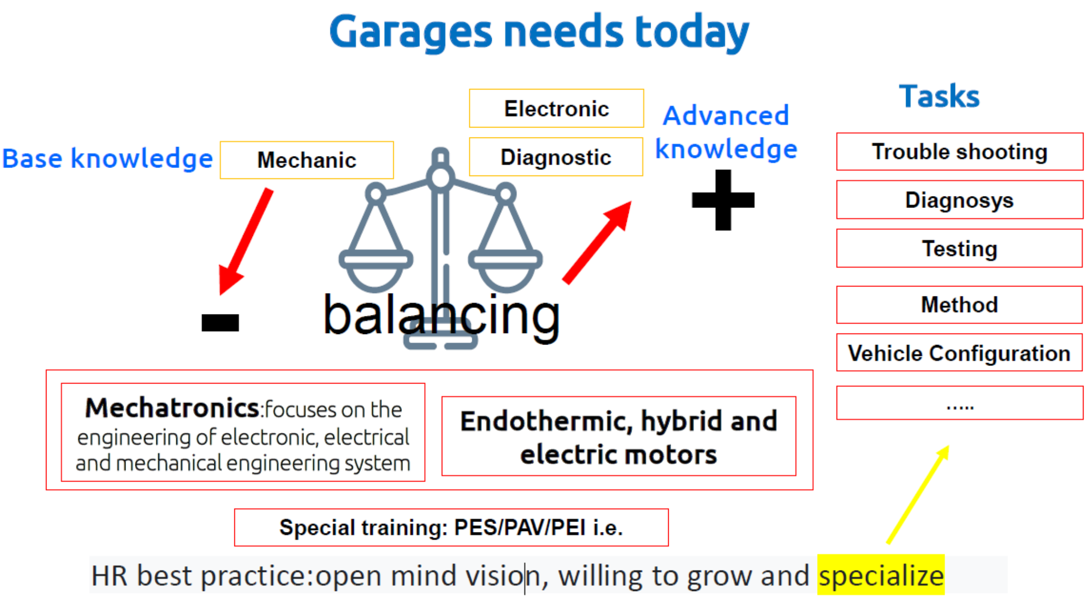
Besides the configuration and layout of the training workplace as well as the equipment and tools, it is strategic to think about which kind of knowledge and skills should the future automotive workers develop since their VET education stages, in order to support the sustainability and digital transition of the whole sector towards the EU Green Deal goals.

According to the gap analysis performed by [Zener Italia] Company, based in Turin, Italy, the discussion about the evolution of the training contents, methodology and skills needs should be based upon the following topics and questions:

- Deep Analysis of the real company needs to build effective school/company education programs;
- Which are the skills that the company is looking for today and in future, considering the EQF 3/4/5 levels?
- The evolution of vehicles on board electronics: what has changed since EV and connected vehicles started to spread, and which transversal skills must be acquired/evaluated?
- Ability/mindset to measure, develop and evaluate before asking trainees to put their hands on EV parts: availability of information/tools and knowing how to process them.



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As already predicted by “The Workshop of the Future” study by Innovam, as e-mobility spreads further there will be less request of base knowledge about general mechanics, with a tendency to shift to the management of the mechatronical engineering systems. On the other hand, there is already an increase in the demand of advanced comparative knowledge between endothermic (ICE), hybrid and electric engines, with specific skills related to troubleshooting, diagnosis, testing and vehicle configuration. According to such view, VET Trainees should become familiar to:

Electrical wiring diagrams and schemes

Diagnostic tools like oscilloscope and multimeter

Mastering the relation among component > system > vehicle DTC (diagnostic trouble code) and diagnostic strategies

Simulating failure of the electronic system within an HEV or EV car

ECU's management, calibration and parameter settings

Knowledge of the OEM/manufacturer assistance portal to understand procedures, configuration parameters and fault codes

Equipment & Tools to be used

Oscilloscope

Diagnosys (DTC)

```
Details:
  406A810F [C 006A - 81 - b00001111]: MultiaxisAccelerationSensor_InvalidSerialDataReceived
      Syntom MultiaxisAccelerationSensor_InvalidSerialDataReceived
      WarningLamp off;        TestCompleted yes;      TestSinceLastClear Completed;   Fault Present
      SnapshotRecordNumber 1 :
        SnapshotRecordNumberOfIdentifiers 55
        ECU time stamp = 66213 min
        ECU time stamps from Key On = 15 sec
        Key On Counter = 60
        DTC Failure type byte = 0x81
        Odometer = 50033 km
        Vehicle Speed = 0 km/h
        Battery Voltage = 13.50 V
        unknown RDI FE13
```

DTC Table: symptom,condition,validation,healing time, recovery...

[DTC code] Component / Function	[Fault symptom] Symptom	Detection conditions	Possible causes	Fault detection mode	Validation time	Healing Time	MIL Lamp	Effect of recovery
P0220 Accelerator pedal sensor 2	[0001] sc Vbatt/5V or oc of sensor Gnd	Po, Cr, Er, Vr	Voltage above upper limit	ENABLING CONDITION: The check is enabled if no failure of the sensor supply 2 is present ERROR RECOGNITION: The sensor raw signal (voltage) is above APPCD_uAPP2_SRCMax_C (3000.978 mV).	APPCD_DebSRCHighDef_C (240 ms)	APPCD_DebSRCHighOK_C (200 ms)	ON1	R1+R10+R37+ R38+R39

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Besides describing the future trends affecting the automotive workshop from 2020 to 2040, Innovam also points out the most relevant knowledge and skills given the deep changes in the garage layout and organization:

3 Changes in the future workshop

- The rise in software and connected car applications will produce a large volume of vehicle information and user data.
- Cars will have (extensive) self-diagnostic systems. A technical help desk will support the technician remotely.
- The diagnostic equipment will be universal. You'll take out a subscription, which will give you access through third parties to the requisite factory data, including software updates.
- For the purposes of resolving the diagnosed problem, the technicians will use augmented reality, such as the earlier Google Glass or HoloLens, with mechanics simply following the visual instructions.

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4 Electrotechnical versus mechanical work

- The increase in electrotechnical work will call for mechanics with specific knowledge and experience.
- Cameras, radars and suchlike will be adjusted automatically using smart (AI) equipment.
- Modules and sub-assemblies will be more likely to be replaced than repaired.
- Increased quality will reduce the maintenance needs of Hybrids, ICE cars and PHEVs by 20%.
- The maintenance needs of Full Electric Vehicles will drop by 50 to 75%. The remaining maintenance will be straightforward, limited to wear and tear parts such as replacing brakes, tires and fluids. Oil changes will no longer be needed.
- Repair work will be rare, as replacements will be cheaper.
- Knowledge of ICT will be required for both electrotechnical and mechanical work.

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5 Workshop setup and staff

- The workshop will be divided in mechanical and electrotechnical areas, respectively.
- High-voltage work will require special tools, personal protection equipment and safety procedures.
- Knowledge of ICT will be needed for reading data, for diagnostics and resolution both for electrotechnical and mechanical work.
- Staff will need to be certified on diagnostics with the various software packages.
- The advent of augmented reality tools and self diagnostic systems will bring about changes in terms of required competencies. Staff with a lower level of education who are capable of following instructions for the purposes of replacing parts. And staff with higher level education capable of solving problems running diagnostic procedures.

6 Impact on education

Mechanical
- EQF level 2: Maintenance
- EQF level 3: Maintenance and repair
- EQF level 4: Diagnosis

Electrics/ Electronics
- EQF level 3: Reading data, perform resets and calibrations
- EQF level 4: Diagnosis and repairs
- EQF level 5: Complex diagnosis, flying doctor

HV-systems
- EQF level 2: Only maintenance work on dead HV components. Power source disconnected. EV Instructed Person.
- EQF level 3: Measurements and repairs on HV components. Make sure HV-system is dead (disconnected). EV Skilled Person.
- EQF level 4/5: EV specialist, may work on live systems after specific training only. (Complex) HV diagnosis.

7 Important competencies

General

- Knows how systems work
- Recognizes components and know their function
- Able to read and understand data from ECU's
- Able to find the right procedure in manuals
- Able to understand the procedures
- Able to accurately follow the procedures

HV-systems

- Knows the safety rules
- Follows the safety rules
- Able to check personal protection
- Able to check HV measurement tools
- Understands and follows the 0-voltage procedure of the vehicle

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Further Tools for Virtual / Augmented Reality Training:

Innovam EV Trainer AR App, a mobile application to help any learner train about electric vehicles in a simulated virtual environment.

The application is downloadable on smartphones and tablets from Google Play https://play.google.com/store/apps/details?id=com.Innovam.EVTrainer&hl=it&gl=US

The demo video is available on "Innovation Garage Erasmus+ Project" YouTube Channel.

4. Making the Innovation Garage of Garages happen

The last phase of the process entails the co-design, as well as the co-assessment and evaluation of the e-mobility training programs.

This paper is meant as a guideline for the current VET trainers, both at I-VET or C-VET levels, returning the results of the pilot phase of the IG2 project. It also sets the basis for the planning, delivery and assessment of the next skills-specific training programs related to relevant topics within the HEVs/EVs and avionics / autonomous drive systems.

The co-delivery of e-mobility training programs, jointly performed by VET providers and automotive manufacturers, dealers or business owners, shall be composed of 3 main phases:

Phase 1: Design

Phase 2: Troubleshooting & Testing

Phase 3: Assessment

In addition, a further validation/release phase can be envisaged after the assessment is over, to make plans about potential improvements, re-design or research of alternative solutions positively impacting the didactic methodology.

<u>Phase 1: Design</u>

Design is about planning the training program in all of its possible implications. The best starting point usually entails considering the target groups of the teaching activities and their needs about the development of green skills for the automotive sector.

This approach helps trainers/teachers or company technicians to determine the skills gap that the training activity should be able to address, and subsequently the relevant learning objectives of the experimentations.

Given the e-mobility applied knowledge that trainees should acquire, and given the practical nature of the abilities/skills that future automotive workers should develop too, the core contents of the training program shall be a troubleshooting problem or challenge about HEVs/EVs or avionics systems, suitably prepared or simulated by the VET teachers/trainers and/or company technicians, to be presented to learners for a cooperative problem solving and solution.

While designing the training program for the development of green mobility skills, VET providers and /or company managers or technicians should consider the following issues:

Issue	Remarks
Choosing the VET Target Learners	Options to consider: ● I-VET for young people during secondary education ● I-VET for adult learners willing to upskill or reskill ● H-VET for learners in EQF 5 level courses pursuing a post-secondary certificate ● C-VET for workers currently employed in the automotive sector in need of skills update ● EQF levels: EQF 3 - EQF 4 - EQF 5 involved in the training program Disadvantaged learners: ● I-VET learners from migrant or low social-economical background ● I-VET learners with low achievements at risk of drop or educational failure ● I-VET or H-VET learners with physical or cognitive disabilities ● C-VET learners, currently employed in automotive companies, at risk of losing their job due to low qualification or skills obsolescence
Choosing the Learning Objectives	Definition of Learning Objective (Cedefop, 2014) (a) “statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence” (b) “sets of knowledge, skills and/or competences an individual has acquired and/or is able to demonstrate after completion of a learning process, either formal, non-formal or informal”. Learning objectives should match the knowledge/ skills needs of the target groups, with the potential of lifting them up.
Choosing the Troubleshooting Problem or Challenge	This should be a practical challenge or troubleshooting situation that trainers should be able to address thanks to their previous skills, with room for the acquisition of further abilities with the supervision of a trainer/teacher. Troubleshooting should reproduce or simulate a specific workplace situation where learners can practise HEVs/EVs or avionics specific skills. This phase should be a total “immersive” one, where trainers are completely focused on the procedure of the practical work

	they are doing.
Identifying Entry Level Knowledge & Skills	According to the learning objectives and troubleshooting challenges, VET teachers/trainers should identify the optimal entry level skills of trainers: -The minimum requirements for the learners to exploit the program and develop new skills -The top level of skills beyond which the program is “too easy” for the learners → in this case, either the level of the training becomes harder or the learners are assigned to a more advanced group.
Choosing the setting: personal equipment, technological tools, machinery	The setting must comply with the safety rules about electrical work as well as about the individual protection of participants. All the trainees must complete at least a work safety course, according to the national legislation, before being admitted to the experimentation. If trainees manage high voltage batteries, specific compulsory training must be attended beforehand. The tools and machinery should be chosen by the VET teachers/trainers according to: -the troubleshooting challenge -the learning objectives -the VET learners’ entry skills
Identifying the work procedure	The work procedure depends on: -the troubleshooting challenge -the skills to be developed -the workplace setting including tools and equipments It is just the time sequence and or the logical/consequential procedure that learners should enact for a cooperative problem solving of the troubleshooting challenge
Identifying supervision and scaffolding roles	The training setting should enact the interpersonal relationships happening in the automotive garage. The workplace should provide scaffolding roles and supervisory roles too, helping learners identify both the correct working procedures and the organisational / hierarchical structure of a workshop or manufacturing company.
Learning Outcomes: desired Hard and Soft Skills	These should be the expected outcomes of the experimentation, in terms of technical skills developed by participants - matching the learning objectives stated above, and of behavioural / interpersonal skills of trainees working in

	teams for the achievements of cooperative learning.

Phase 2: Troubleshooting & Testing

This phase represents the actualization of everything that was planned in Phase 1 - Design. It entails running the tests on HEVs/EVs and/or on avionics/electronics/ autonomous drive as designed in Phase 1.

According to the learning objectives and the troubleshooting challenges identified in Phase 1, VET trainers/teachers should decide in Phase 2:

-whether the testing should be done once or multiple times up until satisfactory results have been achieved;

-how many sequences should the troubleshooting operation should be composed of;

-the total duration of the testing (how many hours);

-how many participants at the same time according to the safety requirements and to the workshop/lab/garage capacity;

-whether or not trainees should be splitted up into smaller teams, assigning them to specific roles or operations within the workplace setting.

Troubleshooting should be as "immersive" as possible for both learners and trainers, all of them totally focused on the e-mobility problems to be solved in a team, on the tasks and procedures to be implemented, as well as on performing their respective roles.

VET teachers/trainers in this phase should not evaluate but just monitor the effective and safe run of the experimentation:

-checking safety requirements about electrical work are met and all the individual protection devices are used by people involved

-checking the extent to which learners can work autonomously in the workplace

-decreasing/increasing the difficulty level of the testing according to real time monitoring of the students's performance;

-stepping into the work procedure when learners need some guidance or help because they are stuck in the job or they are not performing the correct procedure;

- monitoring the organisational relationships among learners within the workplace and providing supervisory roles when needed.

Phase 3: Assessing the Troubleshooting Outcomes

After the workplace testing, the next phase of the process is the evaluation. While testing represents the immersive phase of the learning process, assessment represents the reflection on the action: "Was the troubleshooting in phase 2 effective to reach the objectives set in Phase 1?"

Since the Innovation Garage methodology implies co-designing both the learning path and the learning environment from a multiple bottom-up perspective, feedback on such topic should be collected by the multiple actors participating in the experimentations:

- VET teachers and trainers
- Business Technicians
- VET learners

VET teachers and trainers are the ones in charge to assess whether or not the learning goals of the experimentations are achieved and whether or not the expected outcomes match the initial program in terms of knowledge and skills development. Their reports or records, after the testing is over, should keep track of the following:

A. Students' performance and behaviour
B. Achievement of learning objectives
C. Suitability of entry level knowledge & skills
D. Actual development of new knowledge & skills
E. Effectiveness of the supervision and tutoring strategy
F. Effectiveness of the workplace layout and of the practical tools and equipment

Focusing on students' performance and behaviour is a way of monitoring how the teaching program matches the actual profiles of the learners involved as well as their ability to exploit the potential of the training itself. Within such evaluation, teachers and trainers should also assess whether or not learners were engaged, interested and participative, whether or not they were able to work autonomously yet in a team, whether or not they were able to execute the tasks they were assigned to, whether or not they were able to use the appropriate tools and machinery and to apply safety rules attached to electrical work.

The teachers' assessment form could just be a set of open questions about the extent to which each item was successfully delivered during the testing, but it should be combined with further remarks too, about what was missing, not achieved or poorly implemented. Further questions might set a minimum standard for the level of complexity of the experimentation, given the relevant learning objectives, as well as remarks about how to make the testing easier or harder according to the learners' profiles and/or to the EQF level.

On the other hand, feedback from the business technicians - either from automotive manufacturing companies, automotive repair or assistance garages/workshops or dealers, will be very useful to assess whether or not the knowledge and skills that students developed during the testing are actually transferable to the job market and/or whether there's any missing or "nice to have" skill left to learn in terms of operational competencies. Furthermore, business technicians are the ones who might assess the skills gap of VET trainers too, giving insights about the perspective for further development of the teaching role within the automotive sector. Is there any further specific theme or topic that might complete the skills set? Do teachers/trainers need to develop further digital or technical skills or deeper mastery of diagnostic tools to transfer such abilities to their students? Since VET represents the meeting point between the educational offer and the demand of the business sector, how could teachers be more effective in bridging the gap between education/training and the job market?

Last but not least, feedback from VET trainees should be collected too, after any testing or troubleshooting experimentation involving them. It is more effective when it is done somewhat anonymously, so that each participant feels free and empowered to offer veritable and honest opinions about anything being asked. It's important that questions are arranged into a comprehensive questionnaire distributed to learners in a digital format, which is more easy to process after all answers are complete and that can be turned into explainable graphs or charts. For this reason, questions should be delivered in the form of statements which trainees should rate how much they agree with, on a scale ranging from 1 (completely disagree) to 5 (completely agree). If relevant, it could be also useful including short paragraphs with room to express explicit remarks or comments about the topic. Questions should be as much specific as possible and should be turned into actionable feedback for the trainers, allowing them to upgrade or improve the experimentation for the next turn.

Example of questions to be included into the feedback questionnaires:

-effectiveness of the testing for the development of specific knowledge & skills (related to electromobility);

-effectiveness of the tutoring or supervision roles from the teachers/trainers in order to support the learning process;

-usability of the workplace learning environment and of the technical tools/equipment provided to run the testing;

-to which extent the previous knowledge and skills allowed learners to successfully complete the testing;

-to which extent the trainee feels ready for the job market after the e-mobility workplace experience

<u>Note on a potential phase 4: release</u>

The last part of the assessment and evaluation phase is the final release of results. Given the troubleshooting problem or challenge about e-mobility that is specifically assigned to the VET learners, the results of the testing should include a working procedure or sequence of practical tasks/operations to be carried out in the workplace. The results might sort the following outcomes:

-either the troubleshooting procedure is accepted and the sequence of practical tasks is validated

-or the working procedure is not able to produce the expected results and is rejected.

When the working procedure used to solve the troubleshooting challenge is not useful to reach either the expected result (e. g., how to de-energise an HV battery of a HEV/EV) or the learning objectives (structure of an HV battery and HV battery management) should be rejected.

If the procedure is rejected, feedback from the VET trainers and from the automotive technicians should be capitalized to design and test an alternative troubleshooting challenge.

Conclusion: who is this paper for?

This paper represents the outcome of Intellectual Output 1 of “Innovation Garage of Garages” Erasmus+ project, aiming at developing green skills for the automotive sector at VET level.

The specific goal of such a paper is to provide guidelines for VET teachers and trainers willing to introduce e-mobility as a modular or integrated path within mechanics or automotive courses.

Multiple actors co-designing the training contents, the workplace layout and tools, as well as the organisational details of the didactic methodology (roles of trainers, facilitators, evaluation and assessment criteria, is the special footprint of the project. Since “Innovation Garage” is a worldwide methodology to introduce bottom-up multi-stakeholders innovation over the workplace premises, what this project is aiming at is renovating the way which “workshops” or “garage” training is usually performed.

So, this is just an empty box that needs to be filled with automotive-specific contents or a pilot model that needs to be fitted against the regular training courses within a VET organisation.

This Train-the-Trainer paper is suitable both for teachers and trainers at I-VET level (schools, training centres for young people or adults) from EQF levels 3-4, or even for H-VET at EQF 5 level (tertiary education other than university level). Nonetheless, e-mobility training can involve managers, technicians or trainers at company level - either at production houses, or repair workshops, or dealers, whenever workers need to develop or upgrade their skills about the management and maintenance of HV batteries, of HEV/EV vehicles and of avionics/assisted / autonomous drive systems.

Appendix

New Job Roles for the Automotive Sectors
New Skills for e-mobility, BEV/HEV, avionics & servicing

For your reference, please consider the Automotive Job Roles in the following charts.

You can find there a list of Job Roles in Automotive, selected both according to the the EU ESCO classification of codified Job Roles for Automotive (EU Skills, Competencies, Qualifications & Occupations), and from the Sector Skills Alliance for the Automotive Sector «Drives» 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B, aimed at identifying and training new skills for the car and vehicle production sector, from the Sector Skills Alliance for the Battery Sector "Albatts" 612675-EPP-1-2019-1-SE-EPPKA2-SSA-B.

Where the Engineering level (EQF 6) is mentioned, this happens for the sake of completeness and of respect for the original source, but it was not referenced to the partnership's VET level skills profiles within the "Innovation Garage of Garages Project" (EQF 3-4-5).

Job Role	Job Description
After Sales Service Technician	After-sales service technicians provide after-sales service support to customers, such as the installation, maintenance and repair of the sold products. They take corrective actions to ensure customers' satisfaction, resolve technical product-related issues and write customer summary reports.

Automotive Battery Technician	Assembling, installing, inspecting, maintaining and repairing batteries in motor vehicles. Using electrical test equipment to confirm good working condition after installation. Evaluating batteries to determine the nature of power problems. Preparing old batteries for disposal.
Automotive Electrician	Installing, maintaining & repairing electrical or electronic systems in motor vehicles such as: air conditioning systems, lamps, radios, heating systems, batteries, electrical wiring and alternators. Using diagnostic testing equipment to inspect vehicles and find faults.
Automotive Engineering Drafter	Converting the automotive engineers' designs into technical drawings using software. Detailing dimensions, fastening and assembling methods and other specifications used in the manufacture of automotive components, cars, buses, trucks and other motor vehicles.
Automotive Test Driver	Driving prototypes and pre-production vehicles & assessing their performance, safety and comfort. Testing models in various driving situations Preparing reports to help engineers improve their designs and identify problems
Avionics Technician	Installing, testing, inspecting and adjusting electrical and electronic equipment such as navigation, communication and cruise control systems in vehicles. Carrying out maintenance and repair work. Performing functional tests, diagnosing problems and taking corrective action.
Battery Assembler	Welding and assembling the battery components such as electronics parts, wiring, and casing around the cells.
Battery Test Technician	Using positive and negative wired plugs to test battery's resistance capacity. Testing rejected batteries to determine their flaws.
Electrical Cable Assembler	Manipulating cables and wires made of steel, copper, or aluminium so they can be used to conduct electricity in a variety of appliances.
Electrical Equipment Assembler	Assembly of electrical equipment. Assembling product components and wiring according to the blueprints.
Electrical Equipment Inspector	Checking finished electrical products for physical defects and faulty electrical connections. Recording inspection results Sending faulty assemblies back to production.

Electrical Mechanic	Installing, repairing & maintaining mechanical / electrical components of machinery, tools and equipment. Testing electrical parts to ensure efficiency and make improvements accordingly.
Electrical Supervisor	Monitoring the operations involved in installing and servicing electricity cables and other electrical infrastructure.
Electronic Equipment Assembler	Assembling of electronic equipment and systems. Assembling electronic components and wiring according to blueprints and assembly drawings. Assisting in quality inspection and equipment maintenance.
Electronic Equipment Inspector	Checking electronic equipment for any defects and malfunctions. Ensuring that the equipment is correctly assembled according to specifications and national and international regulations.
Fire Service Vehicle Operator	Driving and operating emergency fire service vehicles such as fire trucks. Emergency driving and assist firefighting operations. Ensuring that all material is well stored on the vehicle, transported and ready for usage.
Microelectronics Engineering Technician	Development of small electronic devices and components such as micro-processors, memory chips, and integrated circuits for machine and motor controls. Building, testing, and maintaining the microelectronic systems and devices.
Motor vehicle assembler	Motor vehicle assemblers install and put prefabricated motor vehicle parts and components together. They inspect the motor vehicles for defects, and test the assembled equipment for proper performance and conformity to quality standards.
Vehicle Electronics Assembler	Setting up equipment & accessories in motor vehicles such as CD players and GPS. Using electric drills and routers to install and examine malfunctioning electronic systems.

Erasmus+ DRIVES Development and Research on Innovative Vocational Education Skills Source: https://www.project-drives.eu/en/driveslearningplatform	
Job Role	**Job description**
ADAS /ADF Testing & Validation Engineer	The purpose of the job role is to generally have an overview of connected and automated driving. The ADAS Testing and Validation Engineer knows the development steps: simulation, laboratory, proving ground and public road testing and also the homologation, which has not yet been fully standardized. The ADAS/ADF testing and validation engineer has a common overview for developing, maintaining, executing, tracking, and reporting the testing and validation processes for ADAS functions. Given the importance of road safety, the effective development requires standardisation.
Sensor Fusion Expert	The expert uses sensors & data fusion to support the production of autonomous intelligent vehicles; Anticipating failures, detecting malfunctions, and ensuring that automated vehicles can operate safely while on the road.
Connected Vehicles Technician	Understanding the design and the structure of devices and applications that connect vehicles and exchange data, in order to provide the vehicle users with a proper description of those devices and applications.
Automotive Cybersecurity Tester	-Automotive cybersecurity norms -Cybersecurity test plan and test suite, which allows to simulate attacks.
Rubber Technologist	Understanding of rubber material, processing methods, behavioral phenomena and compounding methodology.
Functional Safety [Engineer]	Electronic and software faults can lead to failures in cars which can be hazardous, such as e.g. no steering, steering blocking, no brake, self-driving car decisions etc. It is necessary to implement hazard and risk analysis, safety goals, safety concepts following specific design methods, and reaching test coverage applying safety relevant test design techniques.
Highly Automated Drive Engineer	Designing & testing complex vehicle control systems; knowledge about vehicle dynamics and modeling; familiarity with vehicle sensors and signal processing, and the decision-making methods that controls vehicle motion
Automotive Mechatronics Expert	With rising degree of electrification and digitalization of automotive systems, an effective integration of the domains mechanics, electrics and information technology plays a significant role in automotive development processes. Besides engineering expertise in each of the domains, vehicle manufacturer and supplier increasingly need human resources for the management, development and administration of mechatronics systems throughout the entire value creation chain. This includes conception, design, simulation, manufacturing engineering as well as production, logistics, maintenance and quality management of mechatronics systems, which are composed of modules and components of the three mentioned domains.
Sustainability Manager	Internal auditing, analysing sustainability issues within the company and introducing waste and waste minimization practices;

	Following developments in legislation, environmental technologies and waste reduction.
Robotic Technician	Diagnosing and repairing faults on a robot system, program robots and understand robot processes. Automated Manufacturing Systems, Maintenance of robots and Software Implementation/Techniques.
Predictive Maintenance Technician	Implementing methods of data analysis using data collected from the sensors

Erasmus+ albatts Source: https://www.project-albatts.eu/en/skillscards	
Automotive Repair and Inspection Personnel	Electric vehicle (EV) repair and maintenance personnel are responsible for repair and maintenance of electric vehicles.
Battery Manufacturing Technician	A battery manufacturing technician is responsible for the production of batteries in a manufacturing facility.
Battery Module Assembly Technician	A battery module assembly technician is responsible for assembling battery modules in a manufacturing facility.
Battery Recycling Technician	A battery recycling technician is responsible for the collection, transportation and processing of used batteries in a recycling facility.
Quality Technician	A battery quality technician is responsible for ensuring the quality of batteries and battery systems during the development and production phases.

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"Innovation Garage of Garages"

IO2 – Intellectual Output 2

Training programme on the first assembly and installation of new vehicle electrification technologies, based on work-based situated learning methodology within the innovation garage

Output Type: Open / online / digital education

OER – Open Educational Resource

The project is funded by ERASMUS+ Programme of the European Union. The content of this material does not reflect the official opinion of the European Union, the European Commission and National Agencies. Responsibility for the information and views expressed in this material lies entirely with the author(s). Project number: 2020-1-IT01-KA202-008555

Training Program on HEV/EV installation & assembly

Language: English

Author:

Innovation Garage of Garages Partnership

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Innovation

Garage of Garages

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Intro: the learning model

Since VET providers maintain close cooperation with the industrial sectors, especially within the automotive field, workplace training is the most valuable asset that educational institutions hold to develop job-related skills, facilitating the learners' transition into the labour market.

In this view, the "Innovation Garage of Garages" project (named "IG2" below), holds the purpose to bring VET providers and automotive companies together (either construction houses, OEMs manufacturers, dealers, car-repair workshops) to co-design training paths & learning environments suitable for the development of green mobility skills, in terms of:

a-learning goals & contents;

b-layout of the training workplace;

c-tools, machinery and equipment.

According to the panorama of the green skills and job profiles within the Automotive sector, identified in the IO1 paper, the main 5 work processes that IG2 project deals with are:

IO2: Installation & Assembly of EV/HEV engines

IO3: Maintenance of EV/HEV engines

IO4: Configuration & calibration of Avionics systems in e-vehicles

IO5: Maintenance of Avionics systems in e-vehicles

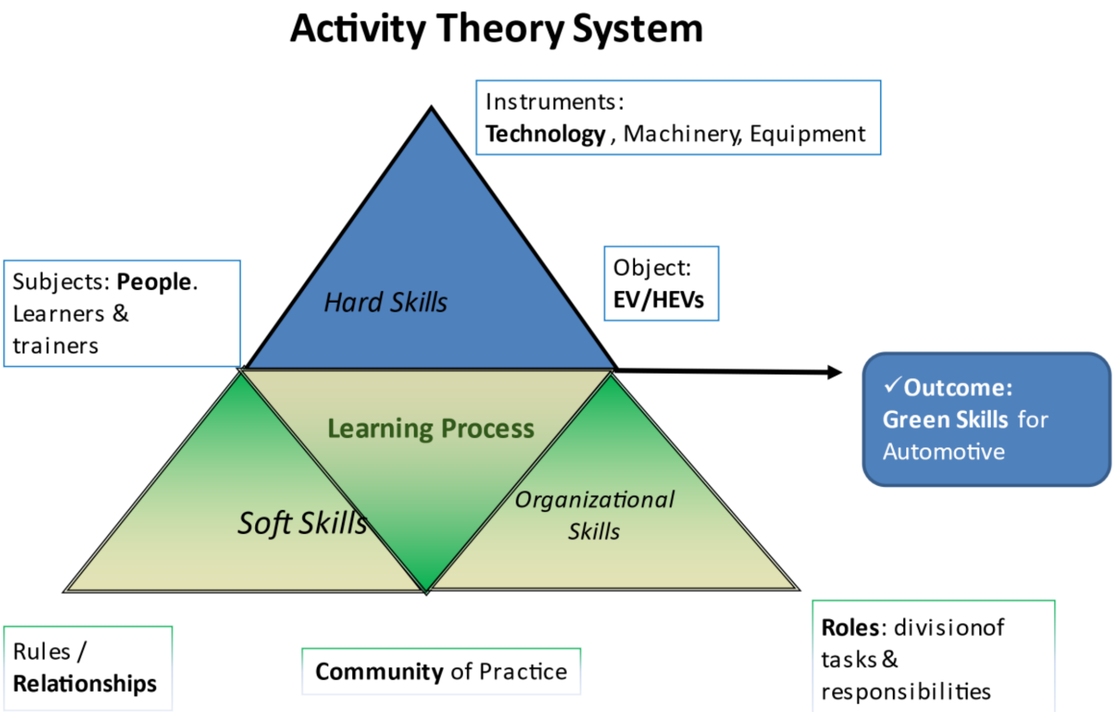
IO6: After-sales assistance & safety issues related to EVs/HEVs

The training environment should make practical learning accessible and inclusive, and students should learn from work processes and organizational structure, as well as use technological assets that are the closest possible to the real workplace layout.

This is what IG2 partnership agreed to call "situated learning", identifying the dynamics of a training environment equipped with technological tools, where learners are immersed into a productive process governed by supervisors performing a mentoring and leading role, aimed at manufacturing a given product.

The learning model inspiring the project methodology is the "Activity Theory" framework by Yrjö Engeström (1987/2015), representing the third generation of academic researchers studying the topic, after the contributions of cultural-historical psychology from the Russian Vygotsky to Leontyev.[1]

[1] For a very introductory documentation over the "Activity Theory" system please see:
- Andy Blunden "Engeström Activity Theory and Social System", 2015



According to such model, the overall learning process is composed of two main dimensions: the immersive experience of actually doing some activity or of producing a real product within a given environment, such as the school lab or the training facility, or workplace itself. This is the dimension where the e-mobility hard skills are being developed, thanks to the interaction of 3 main elements: people (learners & trainers) as *subject* of the process; tools (such as technology, equipment and machinery) as *instruments* making the learning process come true; the *electric/hybrid vehicle* or one or more of its components, as the *object* of the learning process itself. The outcome of the interaction of such 3 elements is the expected learning goal itself for the relevant testing, or, more generally, the green skills for the automotive sector.

Underneath the upper triangle, the Activity Theory puts the hidden or intangible part of the learning process, which is related to the development of all the soft skills implied by interacting within a complex organisation of people. This is what happens to workers in a company, but workplace learning or workplace simulation actually reflects the very same dynamics. As a matter of fact, within an automotive production site or within a car repair workshop, for example, workers are assigned different roles, responsibilities and tasks which actually shape the interpersonal relationship happening over there. VET learners, either in their initial training at school, or involved in lifelong and continuous training at work, are immersed in a community of

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- Oliver Ding, [Yrjö Engeström: the Activity System Model](), 2021

practice, where knowledge, skills & behaviours are shared, promoted, rewarded or even confuted or rejected.

IG2 project, by bringing together VET providers and companies, aims at co-designing learning experiences for the development of e-mobility skills, keeping in mind such behavioral and organizational learning model.

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1. Referencing Output 2 e-mobility skills to the current job qualification frameworks

Output 2 of the IG2 project is focused on the development of skills related to the first **assembly** and/or installation of **EV/HEV engines** or of relevant **sub-components**.

According to IG2 partners, such tasks can range from simple and basic ones, attainable from EQF 3 operators or even lower, e.g. C-VET operators achieving EQF2 vocational qualifications, to technical or supervisory roles (EQF 4 - EQF 5).

Output 1, outlining the train-the-trainers program for VET teachers willing to introduce e-mobility in their didactic courses, collects the job qualifications in the automotive sector according to the ESCO framework and from the job-profiles and skills card classified by the Erasmus+ Sector Skills Alliances DRIVES 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B (for the general automotive sector) & ALBATTS 612675-EPP-1-2019-1-SE-EPPKA2-SSA-B (specifically for the battery sector).

According to such classifications, Output 2 refers to the following job roles matching the EV/HEV engine assembly operations:

	DRIVES Development and Research on Innovative Vocational Education Skills	albatts
Motor vehicle assembler		EV Automotive Repair and Inspection Personnel
Automotive Electrician		
Electrical Cable Assembler		
Electrical Equipment Assembler		
Electrical Equipment Inspector		

Electrical Mechanic		
Electrical Supervisor		
Automotive Battery Technician		
Battery Test Technician		Battery Quality Technician
Electronic Equipment Inspector	Robotic Technician	
Vehicle Electronics Assembler		

Among all the e-mobility related job qualifications that ESCO, DRIVES and ALBATTS put together, the one listed above are the ones that are at least partly relatable to the training programs that were designed and tested by the IG2 VET providers' consortium, and that will be described in the chapters below.

2. Designing, testing and evaluating results of training programs about EV/HV engines assembly

During the Pilot Phase of IG2 project (Output 1), partners agreed that the basic structure of any topic-specific program about e-mobility should start with a joint business-VET design phase, including:

– identifying learning objectives,

– setting knowledge or skills entry requisites for VET learners,

– identifying the work procedures to implement,

– setting the training workplace layout and necessary tools/equipment,

– deciding on the expected outcomes of the troubleshooting,

– establishing supervisory and tutoring roles

VET providers were not assigned prescriptive rules about which relevant topic should be chosen for a training program about EV/HEV engine assembly or installation. Multiple reasons usually affect the choice of the specific topic to focus on, and the following criteria should be taken into consideration while evaluating the potential options:

a) whether or not the VET provider is already including specific training modules or contents about EVs/HEVs in the institutional offer;

b) the EQF level of the training course where e-mobility should be taught or introduced for the first time;

c) the general level of technical knowledge & skills of the target learners as well as their behavioural / communication skills and/or their potential fewer opportunities profile

With regards to point a), this is absolutely the most significant and diriment criterion that should guide the choice of VET trainers: are learners already trained about safety precautions around HV batteries and electric or hybrid engines? Are learners already able to read the electrical schemes of the car? Are they already familiar with the structure and components of internal combustion engines whatsoever?

If this is case, it is probably a good choice to delve into EV/HEV engines specific topics such as electrical insulation or HV battery modules checks, or power unit maintenance. On the opposite side, learners who are not trained about electrical risks must never work hands-on with HV batteries. This happens with upper secondary education courses at EQF 3 or EQF 4 levels, where students work just on the mechanical part of engines. In this case, in the first place mandatory electrical safety courses must be attended from students, and demo classes about HV batteries where trainers show the correct battery management procedures without students being involved, or using electronical panels simulating the engine mechanism or the switches of sensors regulating the circuits of the car, are good examples of introductory activities.

Furthermore, VET trainers should take into consideration the general profile of the target learners involved:

-EQF level of the training course and previous knowledge & skills gained by students

-the age of the learners: is it young people in initial learning or is it workers engaged in an upskilling or re-skilling course within C-VET training paths?

-the general life long background of the students involved: is there any type of potential disadvantage represented in the learning group?

This might range from physical or cognitive disabilities, to migrant background or language barriers preventing students from a full exploitation of the learning opportunities, or even age barriers, in the case of underqualified over-50 workers in need of a skill upscale to prevent job loss. In any of such cases, special arrangements should be envisaged by trainers in order to choose the most inclusive and barrier-free training environment possible. In case any learner has a physical disability, the workplace should be designed in a way that the learner is safe throughout the testing, yet he or she can either see the work procedures or operate some of them according to both the work safety procedures and to what the medical conditions allow. In case the learner has a mild cognitive disability, VET trainers should design the experimentation assigning tasks to small students' teams with an appointed leader with a distributed share of duties, so that everybody can be involved in the experimentation with different level of difficulty or responsibilities.

Team work and practical learning is especially recommended and effective in case of migrant learners with little command of the local language, as graphic or synthetic work procedures help understand topics or tasks quicker than a theoretical frontal class.

Evaluation. As a part of O1 train-the-trainer program results, IG2 project partners established a protocol for the evaluation of the work-based testing, to assess to which extent the program itself was successful for VET learners to develop e-mobility skills. Such assessment is a simple form with questions addressed both to VET teachers or trainers, and to business technicians, since the workplace training should be co-designed on both parts.

Teachers or trainers should assess:

– whether or not the learning goals have been met,

– whether or not the work-based testing delivered the expected outcomes,

– to which extent the expected knowledge and skills have been gained by the students or not,

– whether or not the diagnostic tools were used properly,

– whether or not the supervisory and tutoring activities were adequate to provide learners with the guidance they needed.

When relevant, teachers might also provide additional information about the main difficulties overcome, which tasks were missing or not correctly performed during the experimentation, as well as suggestions on how potentially making the experimentation easier or harder according to the learners' profiles.

On the other hand, business technicians should assess to which extent the knowledge and skills that students developed thanks to such a training experience are indeed useful and transferable to the job market. Furthermore, business technicians might as well provide further examples of troubleshooting and diagnostics experimentations on similar topics, that they believe might help learners develop missing skills about working on EVs/HEVs at different EQF levels.

Let's see examples of the training programs that each country team participating in IG2 project designed & tested.

Option 1 - Safety protocols on EV/HEV

The training program was designed & tested by ROC Midden Nederland (VET provider) and Innovam (company), and is targeting VET students attending the following courses:

- First Car Technician (EQF 3)
- First Truck Technician (EQF 3)
- Technical Specialist Car Technology (EQF 4)
- Technical Specialist Truck Technology (EQF 4)

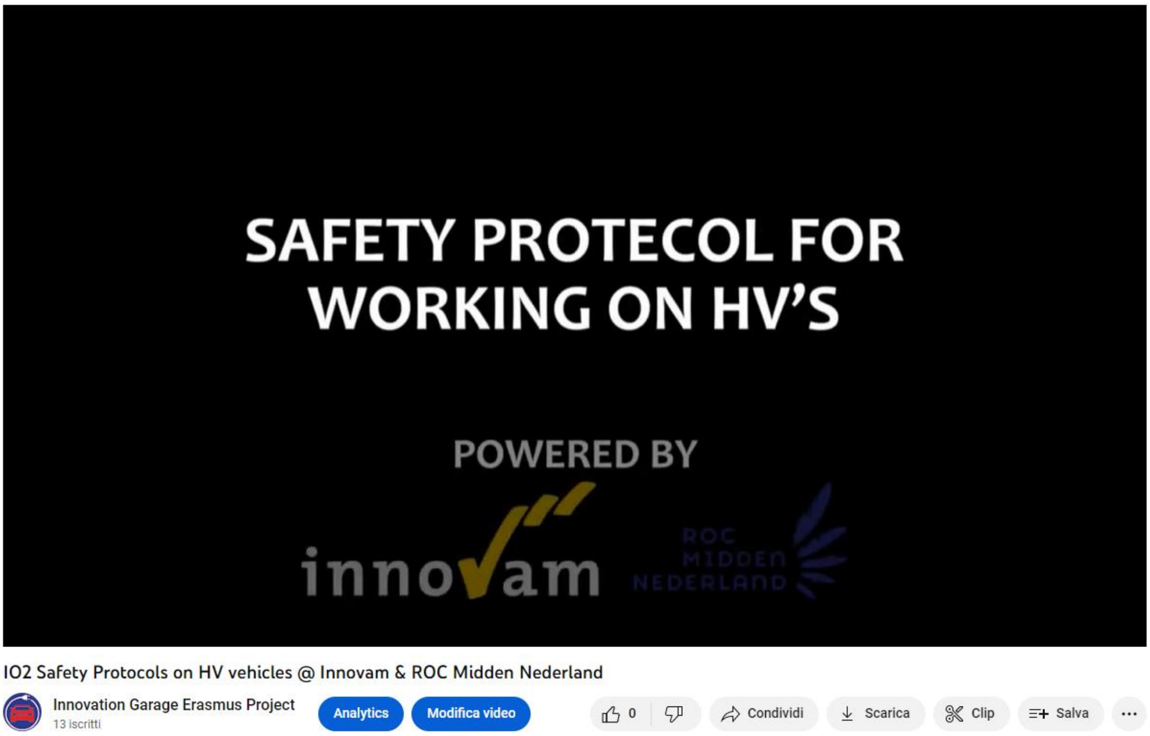
All of them already include, in the regular training paths, teaching contents about the following units:

- Hybrid and electrical drivetrain
- Electric engines
- NEN9140 (EU regulation about electrical works)
- Charging Systems
- Inverter/Converter Battery Management

Nonetheless, the program might be optionable even for trainers with no previous hands-on or theoretical classes about EV/HEV engines, when used as an introductory unit about electrical safety applied to electric or hybrid vehicles. As a matter of fact, ROC Midden Nederland and Innovam do include such topics in a short one-day modular course for students and workers called "Safe working on e-vehicles basics" (see Output 1).

DESIGN FORM	
Task	***Work safe on an e-vehicle***
Learning Objectives	Being able to disconnect the HV-system from the HV-battery. Making sure the system is de-energized and safe to work on.
Entry Level Knowledge (Theoretical)	EQF level 2 Students must be able to recognize all different HV components and their purpose.
Hard Skills involved	Being able to operate a diagnostic tool. Being able to use a two-pole voltage metre. Knowing how to use Personal Protective Equipment
Soft Skills Involved	Being able to read and understand procedures in workshop manuals and diagnostic tools
Equipment & Tools to be used	Personal Protective Equipment Diagnostic tool Two-pole voltage metre
Other Professional Roles involved	An EV responsible employee (EV-nominated person) must be present during execution of the tasks performed by students
Supervision & Tutoring Activities	The teacher must be an EV-nominated person who will guide the students through all the steps to disconnect the HV-system.
Expected Results / Solution	The vehicle is safe to work on after verification that the HV-system is successfully disconnected (HV-system is dead).

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:



Procedure:

-Inspecting if the vehicle is safe to work with: walk around the car and look for any potential damage

-Checking HV wiring for damage under the hood

-Checking car dashboard for errors

-Connecting laptop and checking battery management system for errors

-Securing and blocking the car, marking vehicle with HV signs so any operator in the garage knows HV work is going on

-Securing the car ignition key at least five meters away from it to prevent accidental activation

-Disconnecting HV battery from HV system: removing 12V negative battery cable from 12V battery terminal

-Checking and wearing rubber insulation gloves (class 0)

-Removing service plug from HV battery to disconnect it from HV system

-Waiting 10 minutes for de-charge

-After 10 minutes, remove protection from HV battery terminals and use a multimeter to check no voltage is left

EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes How to make the procedure easier How to make procedure harder	Achieved Breaking it down into separate parts Letting students find the procedures for safeguarding themselves
Expected results	Achieved
Entry level knowledge and skills of the students Preparation	Adequate level to engage in the experimentation. A training session, partly online partly on-site, was delivered beforehand, about working safe on HV-systems, upfront
Equipment & Tools	Used properly
Supervision & Tutoring Preparation	Effective Making sure all the information about safe working are delivered and clearly understood by learners
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete

Suggestion for further development	A graduate or worker entering the job market must be equipped with the right Personal Protection Equipment (PPE).

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Option 2 - Charging an HV battery in a hybrid car

This program was designed and tested by the Lithuanian Team, composed by the VET provider **VAVM - Vilniaus Automechanikos ir Verslo Mokykla** and **Moller Auto Lietuva**, Volkswagen & Audi national dealer, both based in Vilnius.

At VAVM - Vilniaus Automechanikos ir Verslo Mokykla there are two main specialization running on:

-Automotive Mechanic (EQF 4)

-Automotive Electric Equipment Repairer (EQF 4)

Courses do not currently provide a specialisation in HEVs/EVs or avionics circuits, yet work-based training also include maintenance and diagnostics operations on hybrid or electric vehicles. Training modules include contents, knowledge and skills suitable to become the starting point which further e-mobility training can be based upon. Such topics include the following modules:

-Engines technical maintenance

-Transmission technical maintenance

-Automobile electrical equipment repair

-Engines electrical equipment

-Transmission electrical equipment

-Automobile comfort and safety electrical equipment

DESIGN FORM	
Task	***Safety precautions around BEV/HEV*** ***Charging an HV battery***
Learning Objectives	Safe handling of high voltage energy sources in HEV/BEV. Safe HV battery charging.

Entry Level Knowledge (Theoretical)	Basic knowledge of mechanics and electronics
Hard Skills involved	Correct way of using mechanical and safety tools (Multimeter, high voltage resistant gloves, and other specific tools)
Soft Skills Involved	English language
Activities & Procedure required at EQF level (forecast)	EQF 3 level
Equipment & Tools to be used	Multimeter, high voltage resistant gloves and carpet, protective glasses, safety sign, security fence
Other Professional Roles involved	BEV/HEV Specialist/supervisor
Supervision & Tutoring Activities	Overview of processes during theoretical lessons

The training program includes a complete set of operations guiding the learner through a safe preparation of the workplace to operate with an EV/HEV, to measure the charge status of an HV battery and then to provide a full charge. For this reason, the program is targeting learners with previous knowledge and skills about the electrical equipment and safety rules about engines and transmission.

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:

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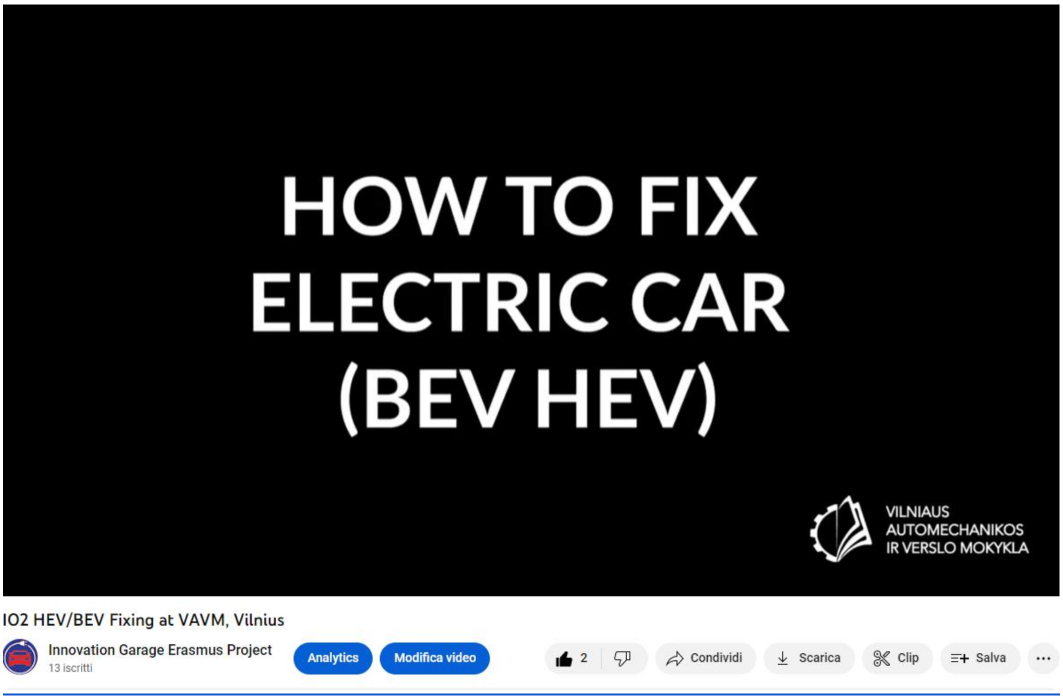


The video illustrates a number of different steps:

1-Preparing a safe workplace and wearing individual safety tools to operate on a EV/HEV

-Setting up a safety zone

-Putting an isolating bumper protection on the back of the car, close to the HV battery

-Putting safety signs with the name of the operator working on the car

-Wearing rubber air tight gloves and protective glasses

2-HV battery charge

-Removing the circuit breaker

-Checking for current in the HV battery with the multimeter: at 0.0 V, the car is safe to start working

-Measuring charge (do not use socket multipliers): the indicator beeps error code and then light is off.

-Measuring charge with a battery break box (with an HV battery plugs lowered to 10:1 for safe training reasons). Measuring is repeated with with HV battery 10:1 plugs - charger DC 10:1 plugs - charger AC 10.1 plugs - inverter/converter 10:1 plugs. Charge is 0 V.

-Re-inserting the circuit breaker

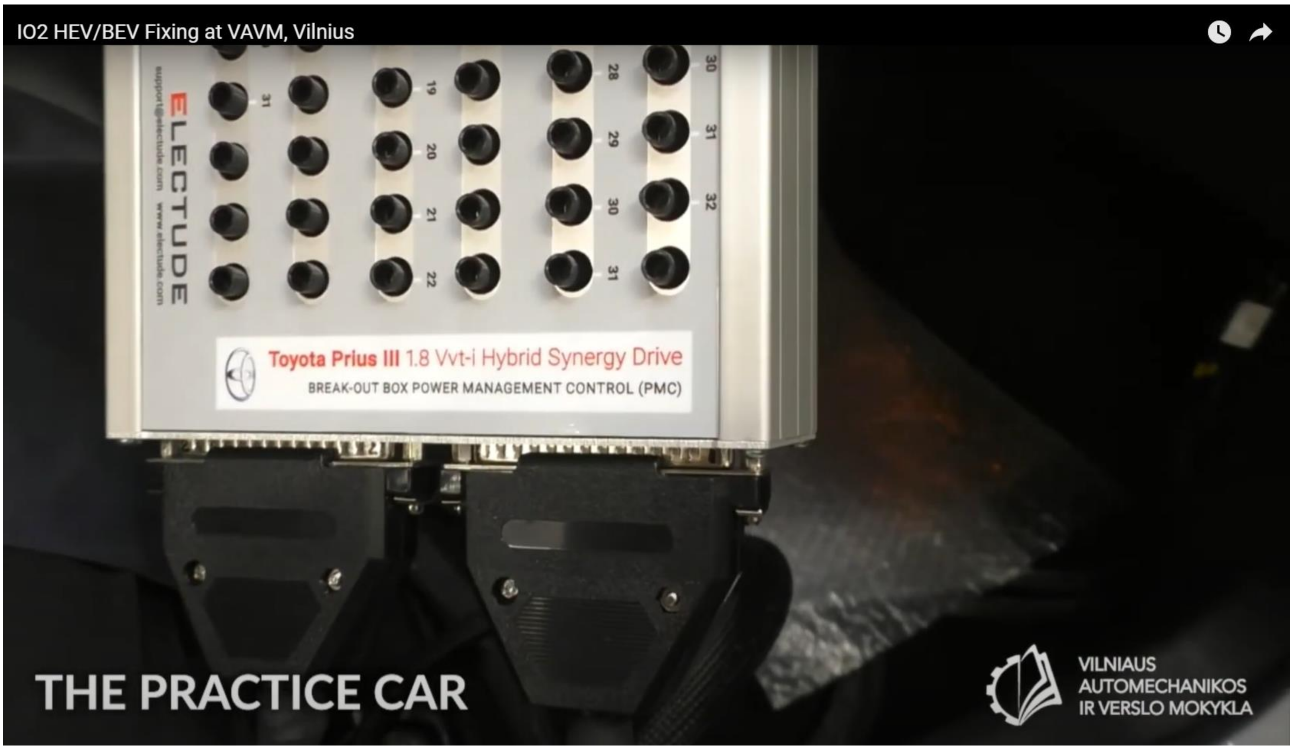
-Insert socket in the charger

-The indicator shows that charging works again

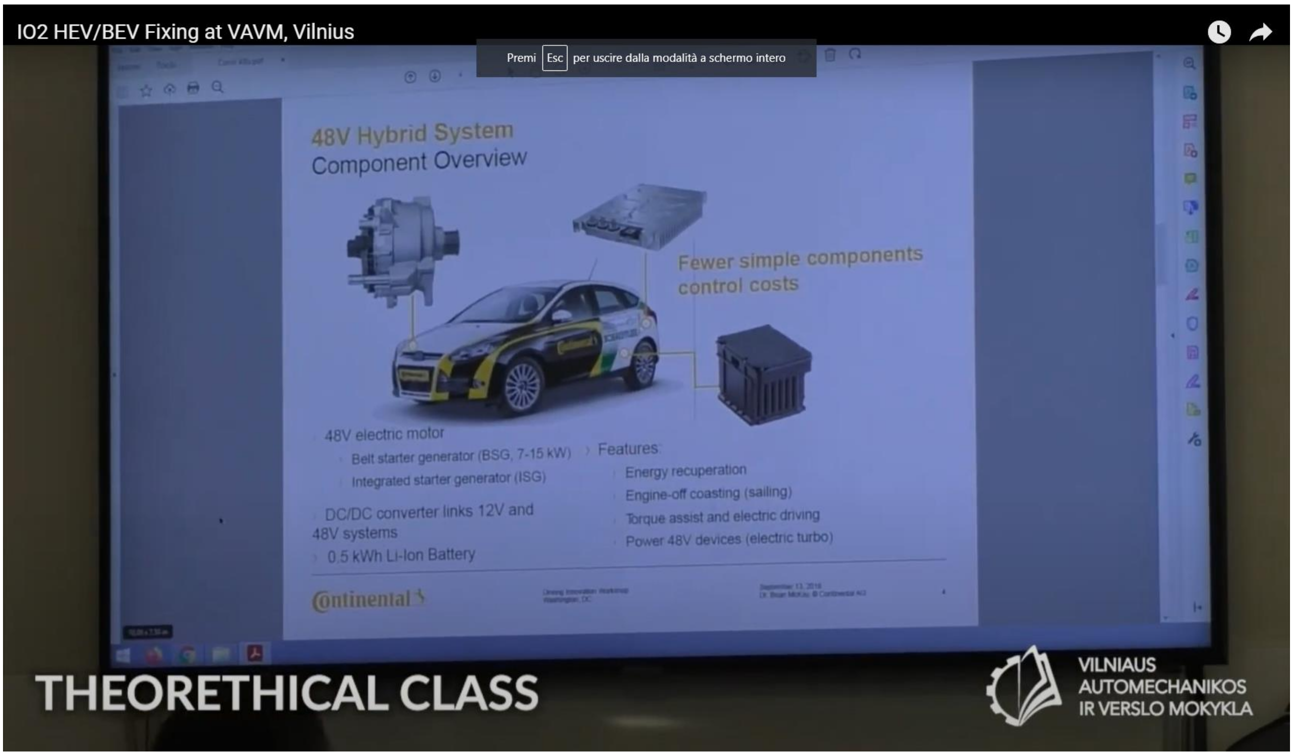
-Measuring charge again with the DC 10:1 battery breakout box: charge is 20.9 V*

The charge is finally on

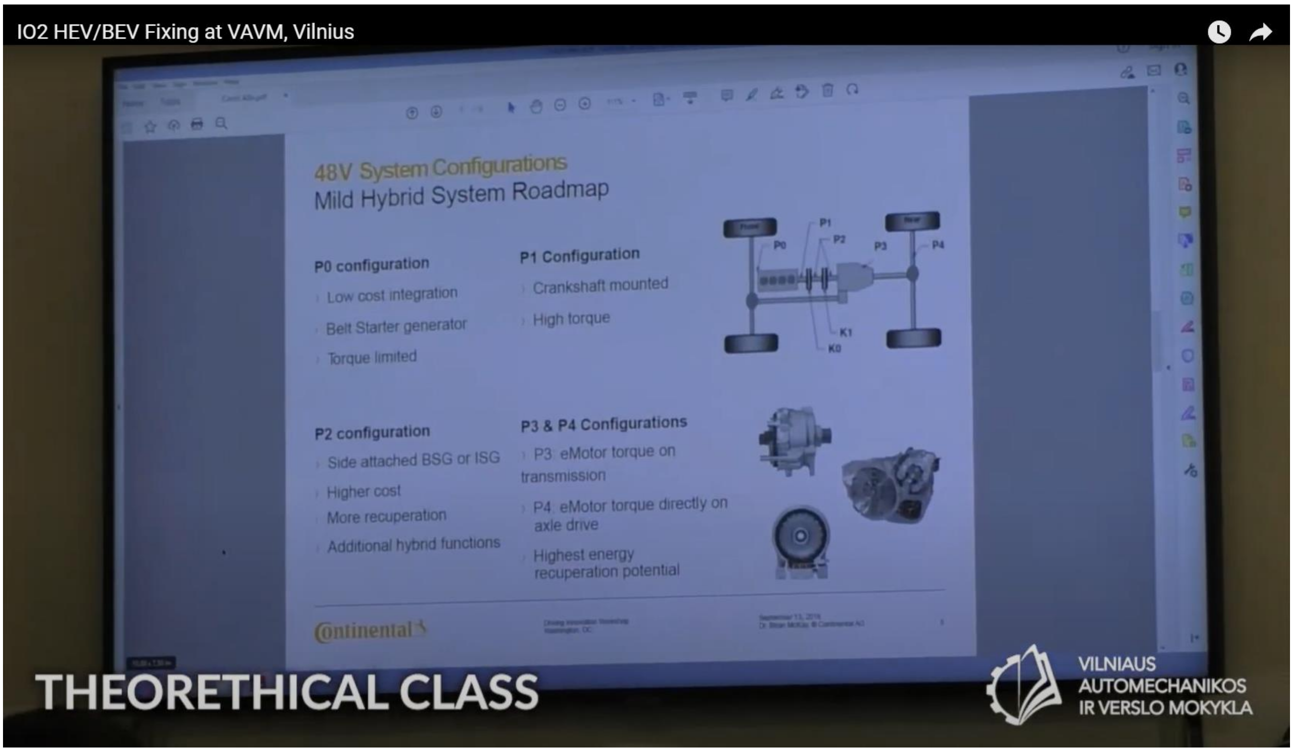
*VAVM uses the Electude Toyota Prius III 1.8 Vvt-i hybrid synergy drive - break out box power management control, further equipped with a separate switch box. The break out box is also equipped with a battery cell + /- unit and a battery module +/- unit



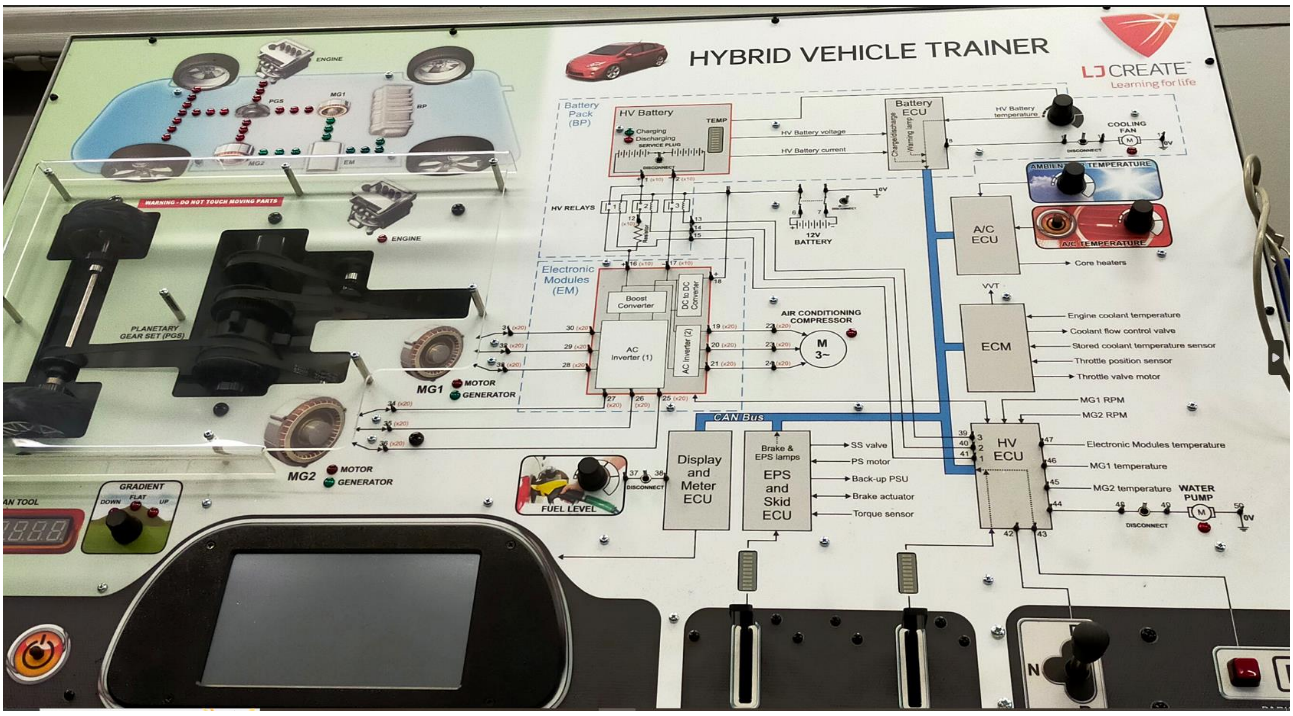
The video is also showing the main topics about electrical transmission that are taught during theoretical classes as a preparatory activity. The first one is battery system component overview.



The second one is system configuration:



Training activities can also benefit from an EV simulation stand with an electronical panel with switches and sensors simulating all the components of an hybrid vehicle, as well as softwares for monitoring the simulation.



EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes	Achieved
How to make the procedure easier	Teachers preparing the workplace and all the necessary instruments/tools in advance
How to make procedure harder	Letting students find all the necessary instruments/tools by themselves according to the task requirements
Expected results	Achieved

Entry level knowledge and skills of the students What is missing	Partly adequate level to engage in the experimentation. Multi-brand diagnostic software knowledge
Equipment & Tools	Used properly
Supervision & Tutoring Potential Improvements	Effective Reducing the number of students in groups
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	A deeper knowledge of brand diagnostic software is useful
Further examples of topic-related troubleshooting problems	
EQF level 3	Charging/discharging HV system
EQF level 4	Checking HV battery leaks
EQF level 5	Checking HV battery control units inside HV battery

Option 3 - Power Unit Operations in an hybrid car

Such a program was run by the EQF 5 level courses within the [Fondazione ITS Maker](), based in Bologna, training Higher Technicians in advanced technology, mechatronics and automotive fields.

Within IG2 project implementation, there are namely two courses with e-mobility related contents:

- Higher Technician in Hybrid, Electric and Endothermic Engines (EQF 5)
- Higher Technician in Electric & Connected Car and Assisted Driving (EQF 5)

Since both profiles envisage high specialisation standards, attainable with a tertiary education course after the general upper secondary certificate (EQF 4), the current IO2 program is only targeting VET learners with prior knowledge and skills about:

- Electrical schemes of vehicle circuits
- Electrical and electronic technologies and applications
- Installation and maintenance technologies and techniques

The IO2 task run by the Fondazione ITS Maker course in hybrid, electric and endothermic engines was about diagnosis and replacement of the output protection fuse to the auxiliary battery.

Technical features: water-cooled Toyota power unit with interlock safety sockets. In the event of accidental disconnection of the cables, the batteries are automatically disconnected.

DESIGN FORM	
Task	***Power unit maintenance: diagnosis intervention and replacement of output protection fuse to auxiliary device battery***
Learning Objectives	Knowledge of the main components that run hybrid and electric vehicles in order to carry out repair work

Entry Level Knowledge (Theoretical)	Principle of electricity and electric power
Hard Skills involved	Holding a secondary education qualification or certificate, minimum experience in the car repair sector
Soft Skills Involved	Being vigilant in the workplace, having a responsible attitude when performing a job
Activities & Procedures required at EQF level (forecast)	Component analysis and repair of damaged parts
Equipment & Tools to be used	Vehicle diagnostic tools, multimeter measuring instruments, dielectric equipment
Other Professional Roles involved	Vehicle recovery technicians and car wreckers
Supervision & Tutoring Activities	Correct use of individual protection tools and correct execution of the steps as mandated in the technical data sheets
Expected Results / Solution	Correct use of protective equipment and measuring instruments, as well as acquiring a certain degree of proficiency in carrying out repair work

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:

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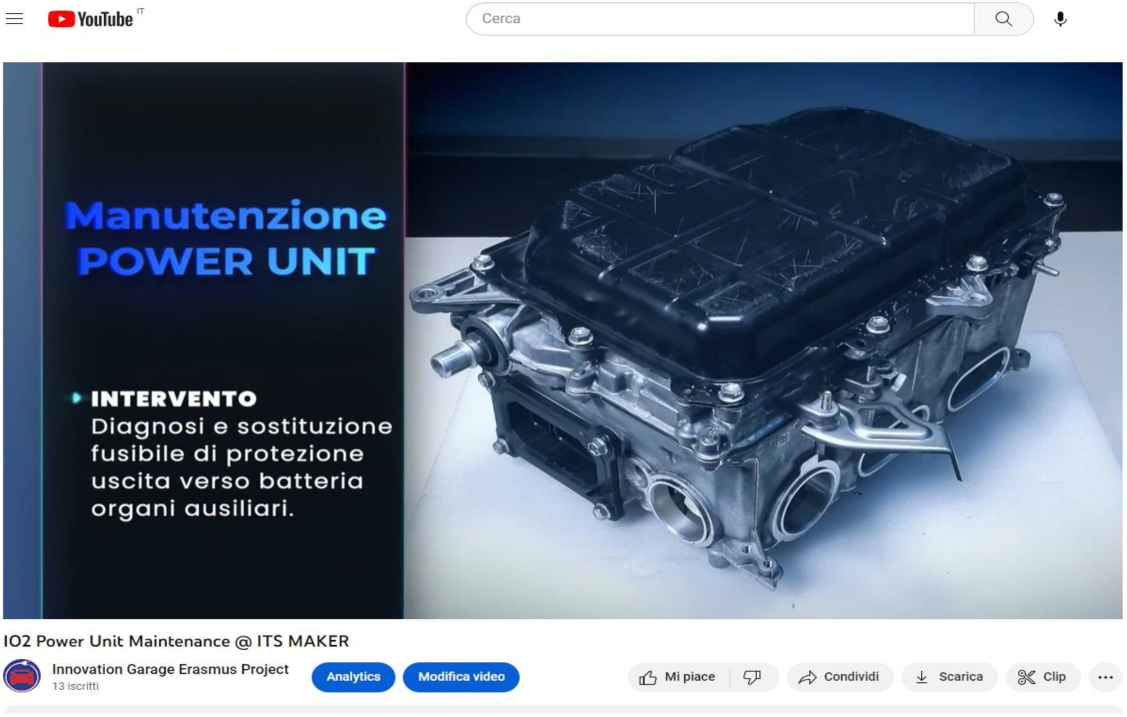


Procedure:

1. Power unit check

-using the multimeter, preliminary checks are carried out to assess the status and any residual voltage

2. Cover disassembly

-using a socket spanner, dismantle and remove all 10 screws that hold the case closed

-heat the edge of the cover with a jet of hot air to facilitate detachment

-use a screwdriver to remove the cover

3. Diagnosis

-use the voltmeter to check which component is possibly damaged

-the absence of continuity of current shows that the protection fuse has failed

4. Component replacement

-with a socket spanner, unscrew the two screws that block the faulty component and remove it

-the functionality of the new component is checked with the multimeter,

-proceed to position and secure the new component

5. Closing the cover

-before positioning the cover, sealant is applied to the edge of the cover

-screw and tighten the 10 tightening screws

EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes How to make the procedure easier How to make procedure harder	Achieved Teachers preparing the workplace and all the necessary instruments/tools in advance No need to make it harder, since the operation is already quite complicated
Expected results	Achieved
Entry level knowledge and skills of the students What is missing	Adequate level to engage in the experimentation. Diagnostic skills on vehicles
Equipment & Tools	Used properly
Supervision & Tutoring Potential Improvements	Effective Even more accurate use of safety protection tools when working with high voltage devices.

Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	A deeper knowledge and skills on repair and maintenance operations
Further examples of topic-related troubleshooting problems	
EQF level 3	Assembly / disassembly of accumulators
EQF level 4	
EQF level 5	

Option 4 - Performing electrical insulation

Such a program identifies a preliminary operation that must be executed anytime an operator is performing an electrical task. Despite being a preliminary task, it should be executed only by instructed people because it involves electrical insulation.

For these reasons, at Göteborgs Tekniska College electrical insulation measurements should be performed by learners attending the e-mobility training suite, which is composed by the following units:

Module Title	Duration	Contents
EV Awareness	4 hours (theory)	• Environmental Issues & Constraints • Market development • Total cost of ownership • Technology involved
Battery System Overview	8 hours (theory and practice)	• Battery Technology • Electric Safety • Battery Management • Usage • Durability
Lithium-Ion battery system	16 hours (theory and practice)	• Cell Formats • Physical Chemistry • Supply Chain • System Design • Production
EV charging and power supply	12 hours (theory and practice)	• Modes • Behaviour • Infrastructure • Business Model • Power Components
Electrical machines and transmission	16 hours (theory and practice)	• Drives overview • Hybrid powertrain typologies • Circuit theory

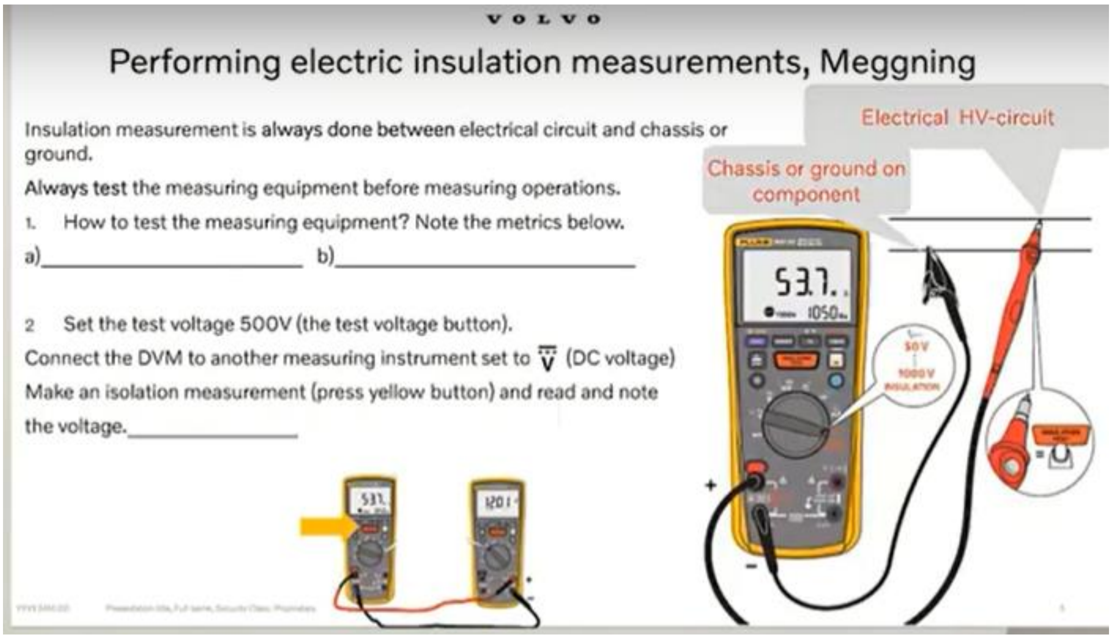
Task: performing electrical insulation measurements on an HV circuit

First thing, the multimeter has to be tested to make sure measurement metrics are fine before proceeding to measure the HV system. The video is showing the correct procedure to make sure electrical insulation is measured in the correct way.

DESIGN FORM	
Task	***Electrical insulation measurements***
Learning Objectives	Knowledge of the use of measuring equipment for HV Knowledge of electrical HV-circuits Knowledge of isolation measurements
Entry Level Knowledge (Theoretical)	EQF level 3
Hard Skills involved	The electric system DC Voltage Operating the equipment involved for measuring Connecting and disconnecting in a safe manner Reading the voltage
Soft Skills Involved	Communicating to team members Understanding manuals
Equipment & Tools to be used	Electrical test equipment (DVM) HV connectors

Other Professional Roles involved	EV responsible employee
Supervision & Tutoring Activities	The EV responsible employee supervision and guiding through the steps of the training activity
Expected Results / Solution	The isolation measurements completed without faulty signals and/or results

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:



EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes How to make the procedure easier How to make procedure harder	Achieved Separating the tasks of measuring into different sections/areas depending on level of education Using the exercise with measurements in one complete flow with more autonomous work
Expected results	Achieved
Entry level knowledge and skills of the students What could be improved	Adequate level to engage in the experimentation. Depending on the students level of previous courses, electrical safety and regulations (EQF 3-4) concerning the actual tasks
Equipment & Tools	Used properly
Supervision & Tutoring Potential Improvements	Effective As always, communication between students and tutor regarding HV safety applies in all above cases and has a constant aim for improvement (5s and Lean)
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete

Suggestion for further development	Depending on level of training (EQF 3 or 4) more HV safety courses apply

Option 5 - Performing electrical diagnosis on vehicle simulation panels

Such tasks were performed by students attending the technical and vocational courses (EQF 4) at IIS "A. Ferrari" in Maranello (Modena, Italy).

Based on the learning objectives of the project - getting students familiar with the electric and hybrid vehicles, batteries and engines, the following study courses were identified as most suitable to run IG2 project's experimentation:

- Maintenance and Technical Assistance (EQF 4)
- Technician for the Construction of Transportation Means - Road Vehicles (EQF 4)

At such a level students attend mandatory work safety courses - both general safety recommendation at work and specific mechanic and electrical risk training, but, given their young age, they are not usually trained as EiP (electrically instructed person) and they cannot work with high voltage batteries or circuits. Because of those restrictions, it is not possible to have students work at power circuits, electrical insulation of EV/HEV, at HV batteries or at e-vehicle charging or de-charging.

On the other hand, electrical simulation panels for specific didactic or training purposes can be used to manage control units in cars through a system of sensors and switches.

IO2 task: managing engine control in traditional ICE engine cars through electrical simulation panels

As an introductory activity to electrical circuits in cars, simulation panels will help students manage the central control unit equipped with sensors regulating different functionalities of the vehicle.

DESIGN FORM	
Task	***Management of control units in vehicles***
Learning Objectives	Correct interpretation of the normal operation of an automotive ICE engine

Entry Level Knowledge (Theoretical)	Basic knowledge of static and kinematic physics and of mechanical principles
Hard Skills involved	Knowledge of the components of an automotive engine
Soft Skills Involved	Autonomy, flexibility, adaptability
Activities and procedure required	Basic diagnostic activities
Equipment & Tools to be used	Electrical simulation panels
Other Professional Roles involved	EV responsible employee
Supervision & Tutoring Activities	Teacher of Mechanics
Expected Results / Solution	Correct interpretation of signals from the standard operation of an automotive ICE engine

Since no hands-on training about HV batteries or EV/HEV circuits is done at this level, theoretical knowledge about electrical powertrain, FMEA (failure modes and effects analysis) and onboard diagnostics can be introduced as an extension to the curricular program.

Additional lecture notes are available in the Training Documentation Folder of IG2 project digital archive.

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:

Topics:

1. Four-channel ABS system. ABS is a braking system. With two sensors we can simulate the whole braking system:

-controlling wheel speed and brake pressure

-operating the various hydraulic valves

-simulating a low battery charge

-simulating an ABS fluid leak

-performing an ABS auto-diagnosis

-measuring the brake fluid level

2. Classic four-stroke engine

The car is controlled by the electronic control unit that controls the fuel injector and injection time, as well as various sensors such as:

-air mass sensor;

-air temperature sensor;

-two lambda sensors, one upstream and one downstream, which monitor the temperature of the exhaust gases. When there is something wrong the control unit then adjusts all the other sensors to fix the whole process.

EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes How to make the procedure easier How to make procedure harder	Achieved Increasing time for practical exercises to become familiar with the diagnostic tools /
Expected results	Achieved
Entry level knowledge and skills of the students What is missing	Adequate level to engage in the experimentation. Basic knowledge of mechanics
Equipment & Tools	Used properly
Supervision & Tutoring Potential Improvements	Effective Peer to peer didactic methods could be suggested. Reduce student number in groups
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete

Suggestion for further development	A deeper knowledge of brand-specific diagnostic software
Further examples of topic-related troubleshooting problems	
EQF level 3	Charging/discharging HV system (theoretical knowledge)
EQF level 4	Checking HV battery leaks (theoretical knowledge)
EQF level 5	Checking HV battery control units inside HV battery (theoretical knowledge)

3. Collecting VET learners' feedback

As stated in the IO1 paper about designing a pilot Train-the-Trainers program about e-mobility, a relevant part of the program itself relies into collecting the learners' feedback about both their appreciation and their self-evaluation about the training experience.

Questions might vary according to the learning objectives of the experimentation and the EQF level of the VET provider, but on a general rule the following criteria should be met in order to administer feedback questionnaires to measure the impact of the training activities:

-forms should be collected anonymously to make sure respondents are free to express their sincere and honest feedback about the training program, either on a paper or digital format;

-questions might be multiple-choice or on a scale, but, in any case, some room for further comments or remarks should be left;

-the extent to which the training workplace helped students develop e-mobility skills should be assessed;

-the effectiveness of the mentoring or supervisory activities should be assessed;

-the extent to which prior knowledge and skills were allowed learners to make the most out of the training program should be assessed;

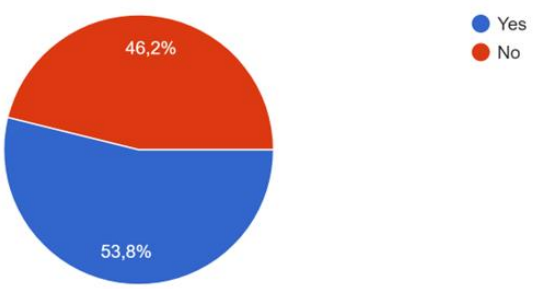
-the perception, on the learners' side, of actual development of e-mobility skills should be assessed;

-the extent to which learners think to be suitably prepared to transition to the job market.

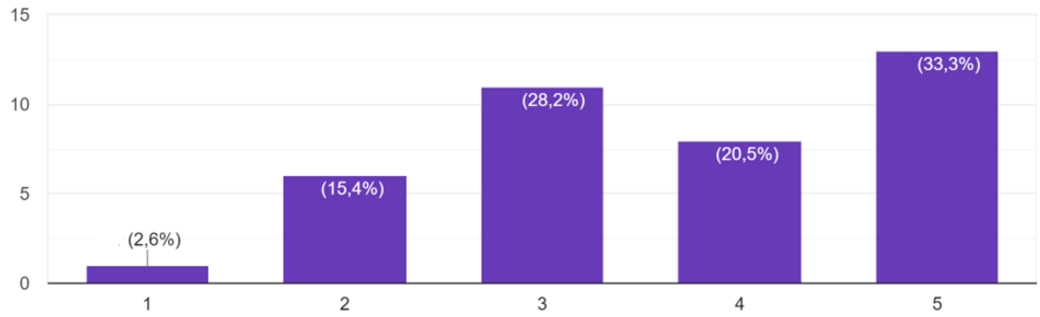
Examples of the collected feedback can be seen from the charts below, which report genderless aggregate data from all the countries and EQF levels involved.

Answers with scale from 1 to 5 mean that respondents were asked to rate the sentence in the questions with a score from 1 (absolutely not) to 5 (absolutely yes).

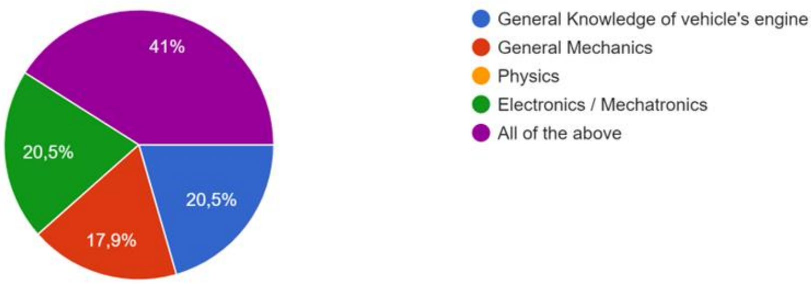
I already took classes in electro-mobility or HEV/BEV before participating in the project



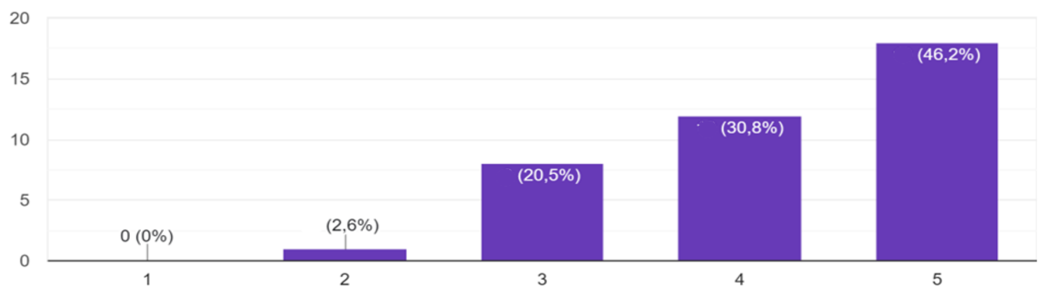
I think my previous knowledge & skills level was enough for me to take part in HEV/BEV testing



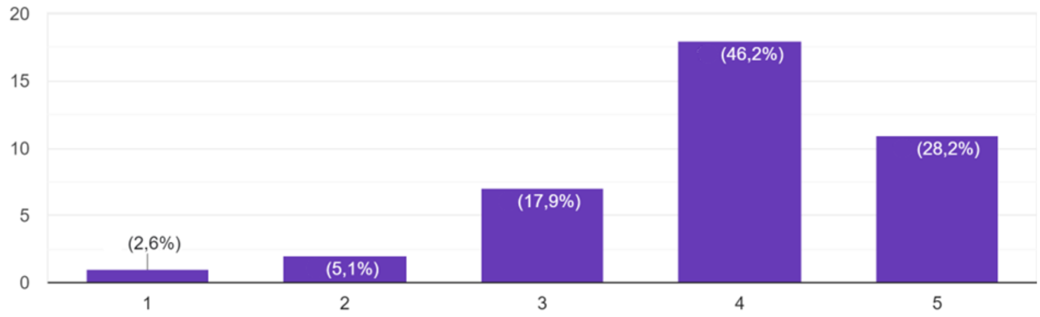
Which of the following was most helpful for you to make the most out of the HEV/BEV testing?



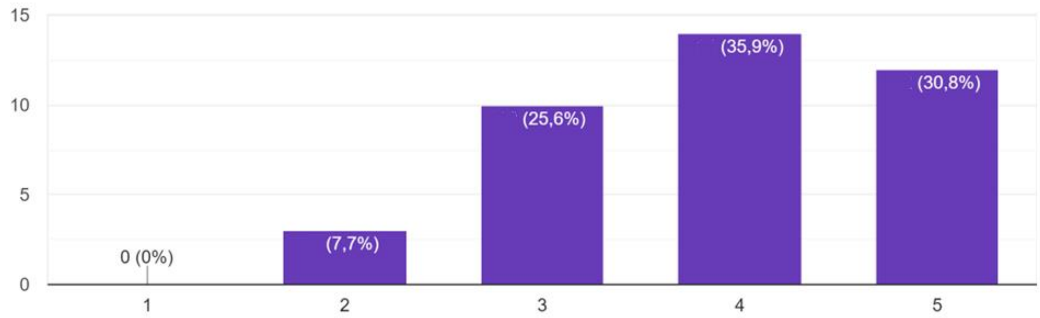
After the testing, I think I developed knowledge and skills about how a to work safely on an HEV/BEV vehicle



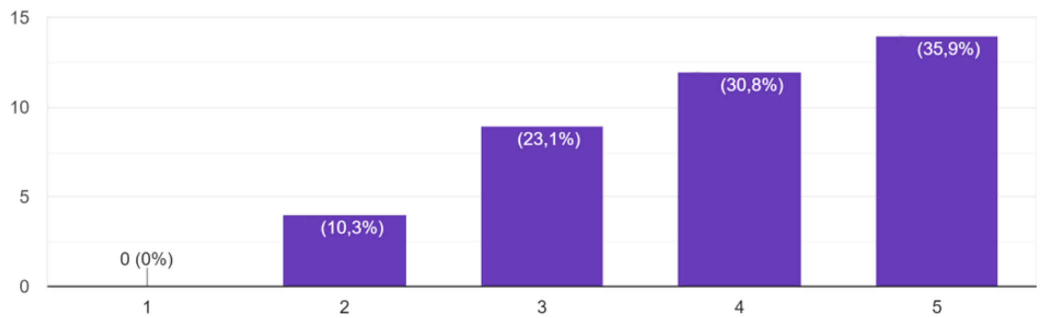
After the testing, I think I developed knowledge and skills about how to perform electrical insulation in a HEV/BEV vehicle



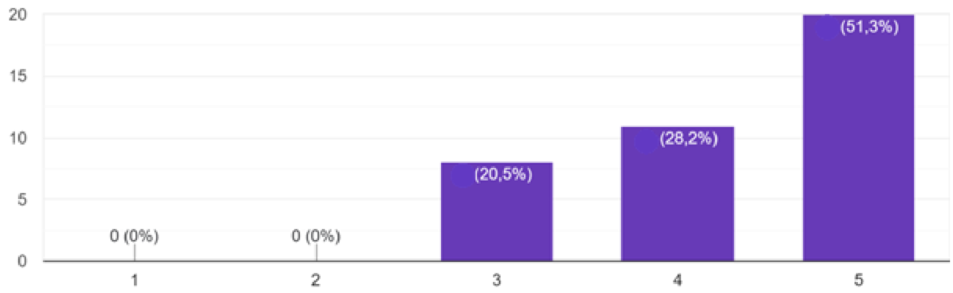
I think I am able to repeat by myself the procedures and work sequences I learned during the testing



I think I was properly trained and supervised during the testing



Thanks to the work-based learning or workplace testing, I think I am better prepared for the automotive job market



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Conclusion: who is this paper for?

This paper represents the outcome of Intellectual Output 2 of "Innovation Garage of Garages" Erasmus+ project, aiming at developing green skills for the automotive sector at VET level.

The specific goal of such a paper is to provide guidelines for VET teachers and trainers willing to introduce hybrid or electric engines, high voltage and their components as a modular or integrated path within mechanics or automotive courses.

Multiple actors co-designing the training contents, the workplace layout and tools, as well as the organisational details of the didactic methodology (roles of trainers, facilitators, evaluation and assessment criteria, is the special footprint of the project. Since "Innovation Garage" is a worldwide methodology to introduce bottom-up multi-stakeholders innovation over the workplace premises, what this project is aiming at is renovating the way which "workshops" or "garage" training is usually performed.

So, this is just a proposal that needs to be customised with specific contents according to the target learners and the regular training courses within a VET organisation.

IO2 paper is suitable both for teachers and trainers at I-VET level (schools, training centres for young people or adults) from EQF levels 3-4, or even for H-VET at EQF 5 level (tertiary education other than university level). Nonetheless, e-mobility training can involve managers, technicians or trainers at company level - either at production houses, or repair workshops, or dealers, whenever workers need to develop or upgrade their skills about the management and maintenance of HV batteries, of HEV/EV vehicles and their components.

Project no. 2020-1-IT01-KA202-008555

“Innovation Garage of Garages”

IO3 – Intellectual Output 3

Training programme on the maintenance - repair of new vehicle electrification technologies, based on work-based situated learning methodology within the innovation garage

Output Type: Open / online / digital education

OER – Open Educational Resource

The project is funded by ERASMUS+ Programme of the European Union. The content of this material does not reflect the official opinion of the European Union, the European Commission and National Agencies. Responsibility for the information and views expressed in this material lies entirely with the author(s). Project number: 2020-1-IT01-KA202-008555

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Training Program on HEV/EV maintenance

Language: English

Author:

Innovation Garage of Garages Partnership

Coordinator: Cisita Parma scarl, Italy

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Intro: the learning model

Since VET providers maintain close cooperation with the industrial sectors, especially within the automotive field, workplace training is the most valuable asset that educational institutions hold to develop job-related skills, facilitating the learners' transition into the labour market.

In this view, the "Innovation Garage of Garages" project (named "IG2" below), holds the purpose to bring VET providers and automotive companies together (either construction houses, OEMs manufacturers, dealers, car-repair workshops) to co-design training paths & learning environments suitable for the development of green mobility skills, in terms of:

a-learning goals & contents;

b-layout of the training workplace;

c-tools, machinery and equipment.

According to the panorama of the green skills and job profiles within the Automotive sector, identified in the IO1 paper, the main 5 work processes that IG2 project deals with are:

IO2: Installation & assembly of EV/HEV engines

IO3: Maintenance & repair of EV/HEV engines

IO4: Configuration & calibration of avionics systems in e-vehicles

IO5: Maintenance of avionics systems in e-vehicles

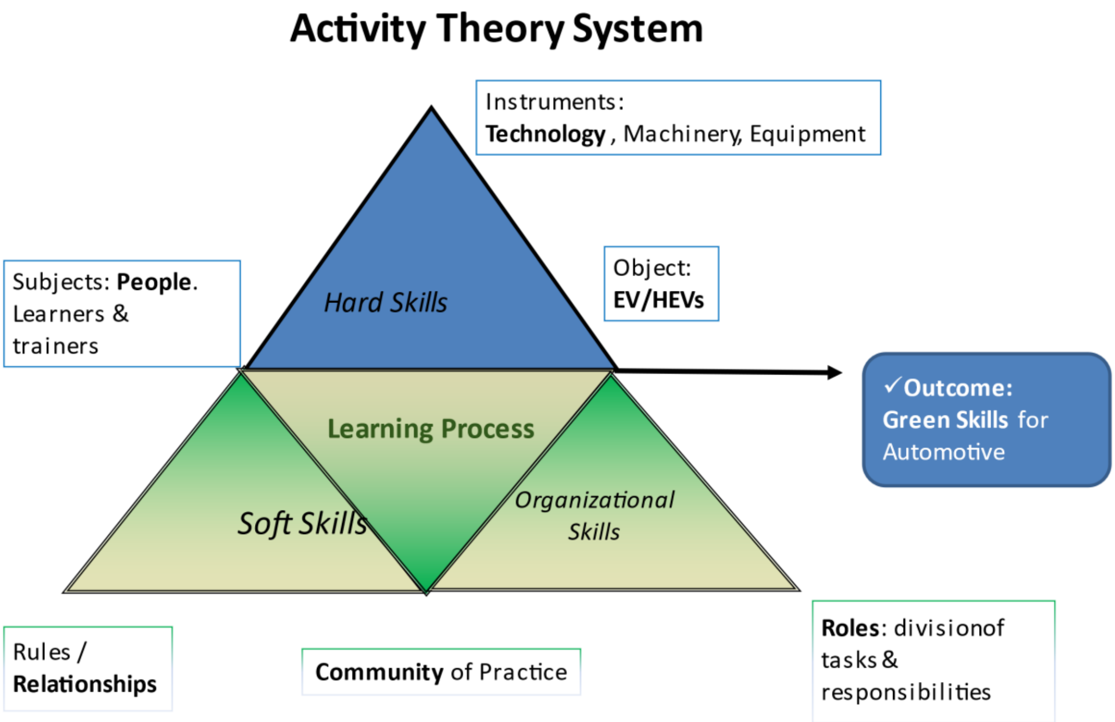
IO6: After-sales assistance & safety issues related to EVs/HEVs

The training environment should make practical learning accessible and inclusive, and students should learn from work processes and organisational structure, as well as use technological assets that are the closest possible to the real workplace layout.

This is what IG2 partnership agreed to call "situated learning", identifying the dynamics of a training environment equipped with technological tools, where learners are immersed into a productive process governed by supervisors performing a mentoring and leading role, aimed at manufacturing a given product.

The learning model inspiring the project methodology is the "Activity Theory" framework by Yrjö Engeström (1987/2015), representing the third generation of academic researchers studying the topic, after the contributions of cultural-historical psychology from the Russian Vygotsky to Leontyev.[1]

[1] For a very introductory documentation over the "Activity Theory" system please see:



According to such a model, the overall learning process is composed of two main dimensions: the immersive experience of actually doing some activity or of producing a real product within a given environment, such as the school lab or the training facility, or the workplace itself. This is the dimension where the e-mobility hard skills are being developed, thanks to the interaction of 3 main elements: people (learners & trainers) as *subject* of the process; tools (such as technology, equipment and machinery) as *instruments* making the learning process come true; the *electric/hybrid vehicle* or one or more of its components, as the *object* of the learning process itself. The outcome of the interaction of such 3 elements is the expected learning goal itself for the relevant testing, or, more generally, the green skills for the automotive sector.

Underneath the upper triangle, the Activity Theory puts the hidden or intangible part of the learning process, which is related to the development of all the soft skills implied by interacting within a complex organisation of people. This is what happens to workers in a company, but workplace learning or workplace simulation actually reflects the very same dynamics. As a matter of fact, within an automotive production site or within a car repair workshop, for example, workers are assigned different roles, responsibilities and tasks which actually shape the interpersonal relationship happening over there. VET learners, either in their initial

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- Andy Blunden "Engeström Activity Theory and Social System", 2015
- Oliver Ding, Yrjö Engeström: the Activity System Model, 2021

training at school, or involved in lifelong and continuous training at work, are immersed in a community of practice, where knowledge, skills & behaviours are shared, promoted, rewarded or even confuted or rejected.

IG2 project, by bringing together VET providers and companies, aims at co-designing learning experiences for the development of e-mobility skills, keeping in mind such behavioural and organisational learning model.

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1. Referencing Output 3 e-mobility skills to the current job qualification frameworks

Output 3 of the IG2 project is focused on the development of skills related to the maintenance and/or repair of **EV/HEV engines** or of relevant **sub-components**.

According to IG2 partners, such tasks can range from simple and basic ones, attainable from EQF 3 operators or even lower, e.g. C-VET operators achieving EQF2 vocational qualifications, to technical or supervisory roles (EQF 4 - EQF 5).

Output 1, outlining the train-the-trainers program for VET teachers willing to introduce e-mobility in their didactic courses, collects the job qualifications in the automotive sector according to the ESCO framework and from the job-profiles and skills card classified by the Erasmus+ Sector Skills Alliances DRIVES 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B (for the general automotive sector) & ALBATTS 612675-EPP-1-2019-1-SE-EPPKA2-SSA-B (specifically for the battery sector).

According to such classifications, Output 3 refers to the following job roles matching the EV/HEV maintenance or repair operations:

	DRIVES Development and Research on Innovative Vocational Education Skills	albatts
Motor vehicle assembler		EV Automotive Repair and Inspection Personnel
Automotive Electrician		
Electrical Cable Assembler		
Electrical Equipment Assembler		

Electrical Equipment Inspector		
Electrical Mechanic		
Electrical Supervisor		
Automotive Battery Technician		Battery Manufacturing Technician
Battery Assembler		Battery Module Assembly Technician
Battery Test Technician		Battery Quality Technician
Electronic Equipment Assembler	Automotive Mechatronics Expert	
Electronic Equipment Inspector		
Vehicle Electronics Assembler		

Among all the e-mobility related job qualifications that ESCO, DRIVES and ALBATTS put together, the one listed above are the ones that are at least partly relatable to the training programs that were designed and tested by the IG2 VET providers' consortium, and that will be described in the chapters below.

2. Designing, testing and evaluating results of training programs about EV/HV engines maintenance

During the Pilot Phase of IG2 project (Output 1), partners agreed that the basic structure of any topic-specific program about e-mobility should start with a joint business-VET design phase, including:

– identifying learning objectives,

– setting knowledge or skills entry requisites for VET learners,

– identifying the work procedures to implement,

– setting the training workplace layout and necessary tools/equipment,

– deciding on the expected outcomes of the troubleshooting,

– establishing supervisory and tutoring roles

VET providers were not assigned prescriptive rules about which relevant topic should be chosen for a training program about EV/HEV engine maintenance or repair. Multiple reasons usually affect the choice of the specific topic to focus on, and the following criteria should be taken into consideration while evaluating the potential options:

a) whether or not the VET provider is already including specific training modules or contents about EVs/HEVs in the institutional offer;

b) the EQF level of the training course where e-mobility should be taught or introduced for the first time;

c) the general level of technical knowledge & skills of the target learners as well as their behavioural / communication skills and/or their potential fewer opportunities profile

With regards to point a), this is absolutely the most significant and diriment criterion that should guide the choice of VET trainers: are learners already trained about safety precautions around HV batteries and electric or hybrid engines? Are learners already able to read the electrical schemes of the car? Are they already familiar with the structure and components of internal combustion engines whatsoever?

If this is case, it is probably a good choice to delve into EV/HEV engines specific topics such as electrical insulation or HV battery modules checks, or power unit maintenance. On the opposite side, learners who are not trained about electrical risks must never work hands-on with HV batteries. This happens with upper secondary education courses at EQF 3 or EQF 4 levels, where students work just on the mechanical part of engines. In this case, in the first place mandatory electrical safety courses must be attended from students, and demo classes about HV batteries where trainers show the correct battery management procedures without students being involved, or using electronical panels simulating the engine mechanism or the switches of sensors regulating the circuits of the car, are good examples of introductory activities.

Furthermore, VET trainers should take into consideration the general profile of the target learners involved:

-EQF level of the training course and previous knowledge & skills gained by students

-the age of the learners: is it young people in initial learning or is it workers engaged in an upskilling or re-skilling course within C-VET training paths?

-the general life long background of the students involved: is there any type of potential disadvantage represented in the learning group?

This might range from physical or cognitive disabilities, to migrant background or language barriers preventing students from a full exploitation of the learning opportunities, or even age barriers, in the case of underqualified over-50 workers in need of a skill upscale to prevent job loss. In any of such cases, special arrangements should be envisaged by trainers in order to choose the most inclusive and barrier-free training environment possible. In case any learner has a physical disability, the workplace should be designed in a way that the learner is safe throughout the testing, yet he or she can either see the work procedures or operate some of them according to both the work safety procedures and to what the medical conditions allow. In case the learner has a mild cognitive disability, VET trainers should design the experimentation assigning tasks to small students' teams with an appointed leader with a distributed share of duties, so that everybody can be involved in the experimentation with different level of difficulty or responsibilities.

Team work and practical learning is especially recommended and effective in case of migrant learners with little command of the local language, as graphic or synthetic work procedures help understand topics or tasks quicker than a theoretical frontal class.

Evaluation. As a part of O1 train-the-trainer program results, IG2 project partners established a protocol for the evaluation of the work-based testing, to assess to which extent the program itself was successful for VET learners to develop e-mobility skills. Such assessment is a simple form with questions addressed both to VET teachers or trainers, and to business technicians, since the workplace training should be co-designed on both parts.

Teachers or trainers should assess:

– whether or not the learning goals have been met,

– whether or not the work-based testing delivered the expected outcomes,

– to which extent the expected knowledge and skills have been gained by the students or not,

– whether or not the diagnostic tools were used properly,

– whether or not the supervisory and tutoring activities were adequate to provide learners with the guidance they needed.

When relevant, teachers might also provide additional information about the main difficulties overcome, which tasks were missing or not correctly performed during the experimentation, as well as suggestions on how potentially making the experimentation easier or harder according to the learners' profiles.

On the other hand, business technicians should assess to which extent the knowledge and skills that students developed thanks to such a training experience are indeed useful and transferable to the job market. Furthermore, business technicians might as well provide further examples of troubleshooting and diagnostics experimentations on similar topics, that they believe might help learners develop missing skills about working on EVs/HEVs at different EQF levels.

Let's see examples of the training programs that each country team participating in IG2 project designed & tested.

Option 1 - Diagnosis on the HV system of an hybrid vehicle

The training program was designed & tested by ROC Midden Nederland (VET provider) and Innovam (company), and is targeting VET students attending the following courses:

- First Car Technician (EQF 3)
- First Truck Technician (EQF 3)
- Technical Specialist Car Technology (EQF 4)
- Technical Specialist Truck Technology (EQF 4)

All of them already include, in the regular training paths, teaching contents about the following units:

- Hybrid and electrical drivetrain
- Electric engines
- NEN9140 (EU regulation about electrical works)
- Charging Systems
- Inverter/Converter Battery Management

Nonetheless, the program might be optionable even for trainers with no previous hands-on or theoretical classes about EV/HEV engines, when used as an introductory unit about electrical safety applied to electric or hybrid vehicles. As a matter of fact, ROC Midden Nederland and Innovam do include such topics in a short one-day modular course for students and workers called "Safe working on e-vehicles basics" (see Output 1).

Current IO3 Task: diagnosis on the HV system of an hybrid vehicle

DESIGN FORM	
Task	***Troubleshoot and repair of an HV system***
Learning Objectives	Being able to identify a problem in the HV-system with a diagnostic tool. Being able to troubleshoot the problem with the proper tools Being able to repair the fault.
Entry Level Knowledge (Theoretical)	EQF level 3 Students must be able to troubleshoot electrical circuits with a diagnostic tool and HV-measurement equipment.
Hard Skills involved	Being able to operate a diagnostic tool. Being able to use a two-pole voltage meter. Being able to use an HV-insulation tester. Knowing how to use Personal Protective Equipment Being able to check and repair HV-components. Being able to recognize electrical hazards and how to avoid them.
Soft Skills Involved	Autonomy Being able to read and understand procedures in workshop manuals and diagnostic tools.

Equipment & Tools to be used	Personal Protective Equipment Diagnostic tool Two-pole voltage metre HV-insulation tester
Other Professional Roles involved	An EV responsible employee (EV-nominated person) must be present during execution of the tasks performed by students
Supervision & Tutoring Activities	The teacher must be an EV-nominated person who will guide the students through all the steps to disconnect the HV-system.
Expected Results / Solution	The HV-problem is identified. The troubleshooting is done correctly and safely according to the procedures in the workshop manual. The fault is repaired correctly. After repair the vehicle is working correctly, no fault codes left in the HV management system.

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:

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Procedure:

Check vehicle malfunctions and other notifications (Volkswagen GTE hybrid car)

Mark the workplace and vehicle, make clear that HV work is being executed.

Check the workshop documentation for the HV disconnecting procedure. Open the service switch and block against unintentional switching on.

Put the ignition key 5 metres away from the vehicle to prevent starting by remote key

Check the electrical insulating gloves carefully (class 0). Get rid of any worn or broken piece of protection.

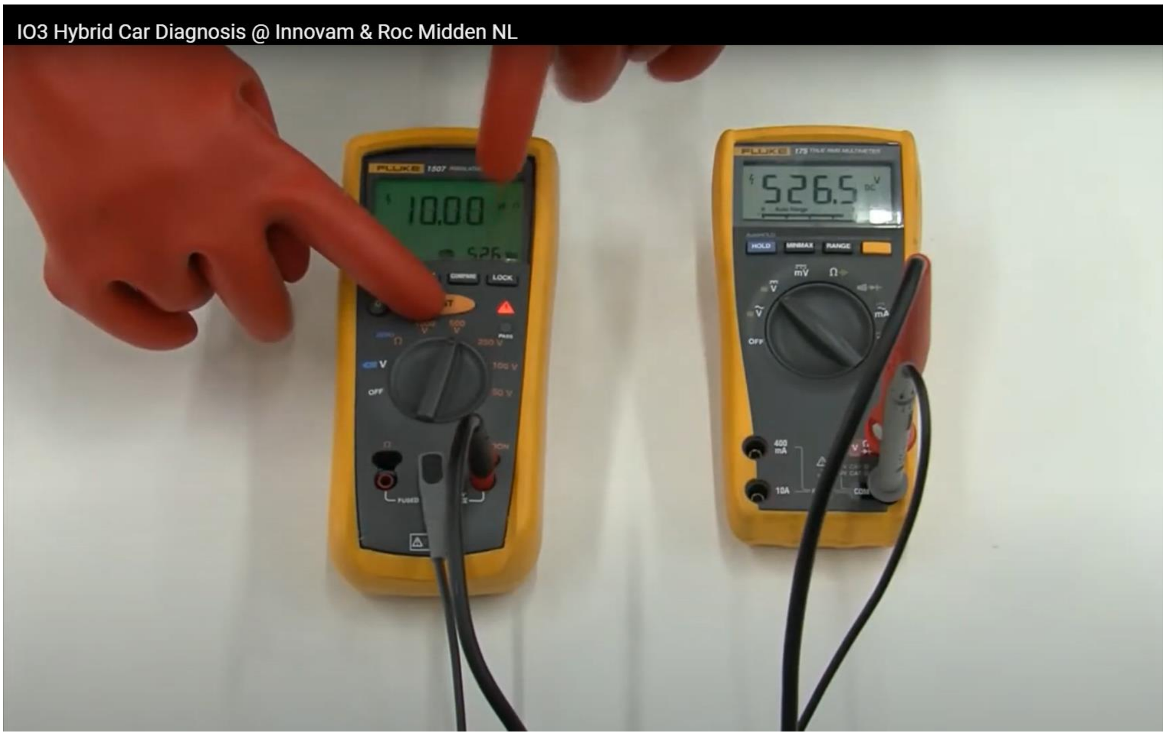
Access the measuring point for executing the “0 volt check” to verify that the HV system is dead.

Verify that the two-pole voltage indicator is at least class 3 applicable to the battery voltage.

Execute the 0 volt check with the multimeter: the tool measures 0 volt, so we can remove the gloves.

Disconnect the suspected failed component for diagnosis

Check the Mega Ohm Meter (also known as “Megger”): caution! Wear class 0 insulating gloves.



In this image, the VET trainer is running an insulation resistance test: first, we’re using a Fluke insulation tester (on the left, also known as “Mega Ohm Meter” or “Megger”) and then we’re introducing a test specimen (on the right). This is a digital multimeter and we're going to exploit the fact that its input impedance[2] is 10 mega ohms as a test specimen.

We’re then setting the test level on the Megger on 500 Volts and we're ready to perform our test.

When the test button is pressed on the Megger, it reads 10.0 mega ohms on a scale of 526 1052 volts.

Keep in mind that insulation resistance values vary with temperature and humidity. According to such measurement, the insulation test is valid.

After the insulation measurement, test the HV engine component according to the workshop documentation: with 500 volts, insulation resistance should be over 550 Mega Ohm.

Electric motor is defective since there is no resistance (around 0 Mega Ohm)! Remove and repair.

[2] Impedance, represented by the symbol Z, is a measure of the opposition to electrical flow. It is measured in ohms.

Check the repaired electric motor. Resistance should be over 550 Mega Ohm.

Build back together, reconnect the e-motor.

Reactivate the HV system and put the service plug back in.

Check the repair: does the HV system switch to “ready” mode?

Clear all digital trouble codes from the OBD (on-board diagnostics) software interface.

Make a test drive and, if no malfunctions are detected, deliver the car back to the customer.

EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes What was missing? How to make the procedure easier How to make procedure harder	Achieved No electrically failed transmission available Preparing only a 12-Volts failure Preparing internal battery faults
Expected results What was missing /wrong ?	Achieved Mismatch of training schedules between students skills’ profiles and prepared vehicles
Entry level knowledge and skills of the students What should be boosted or improved?	Adequate level to engage in the experimentation. Standard safety procedures and knowledge of diagnostic tools
Equipment & Tools	Used properly
Supervision & Tutoring	Effective

Preparation	Making sure all the information about safe working are delivered and clearly understood by learners
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	A graduate or worker entering the job market must be equipped with the right Personal Protection Equipment (PPE).

Option 2 - Safe HV battery removal and diagnostics

This program was designed and tested by the Lithuanian Team, composed by the VET provider **VAVM - Vilniaus Automechanikos ir Verslo Mokykla** and **Moller Auto Lietuva**, Volkswagen & Audi national dealer, both based in Vilnius.

At VAVM - Vilniaus Automechanikos ir Verslo Mokykla there are two main specialization running on:

-Automotive Mechanic (EQF 4)

-Automotive Electric Equipment Repairer (EQF 4)

Courses do not currently provide a specialisation in HEVs/EVs or avionics circuits, yet work-based training also include maintenance and diagnostics operations on hybrid or electric vehicles. Training modules include contents, knowledge and skills suitable to become the starting point which further e-mobility training can be based upon. Such topics include the following modules:

-Engines technical maintenance

-Transmission technical maintenance

-Automobile electrical equipment repair

-Engines electrical equipment

-Transmission electrical equipment

-Automobile comfort and safety electrical equipment

Task: safe procedures for HV battery removal and diagnostics in a Volkswagen E-Golf car.

DESIGN FORM	
Task	***Safety battery removal and diagnostics***
Learning Objectives	Removal, installation, leak test, sealing and anticorrosion coating of high voltage battery in HEV/BEV

Entry Level Knowledge (Theoretical)	Advanced knowledge of mechanics, electronics and software interfaces
Hard Skills involved	Correct way of using mechanical and safety tools (Multimeter, high voltage resistant gloves, leak tester, and other specific tools) Hazardous materials (Sealant, anti corrosion wax, thinner)
Soft Skills Involved	English language for technical terms
Activities & Procedure required at EQF level (forecast)	EQF 3 level
Equipment & Tools to be used	Multimeter, high voltage resistant gloves and carpet, protective glasses, safety sign, security fence, car lifter, battery lifter, wrench tool set, leak tester, dealership software, brushes.
Other Professional Roles involved	BEV/HEV Specialist/supervisor
Supervision & Tutoring Activities	Overview of processes during theoretical lessons
Expected results / solution	Students will know how to prepare, remove, install, leak test, seal and safe handle batteries of BEV/HEV

The training program includes a complete set of operations guiding the learner through a safe preparation of the workplace to operate with an EV/HEV, to measure the (dis)charge status of an HV battery and then to remove the battery and to install and secure a new one. For this reason, the program is targeting learners with previous knowledge and skills about the electrical equipment and safety rules about engines and transmission.

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:

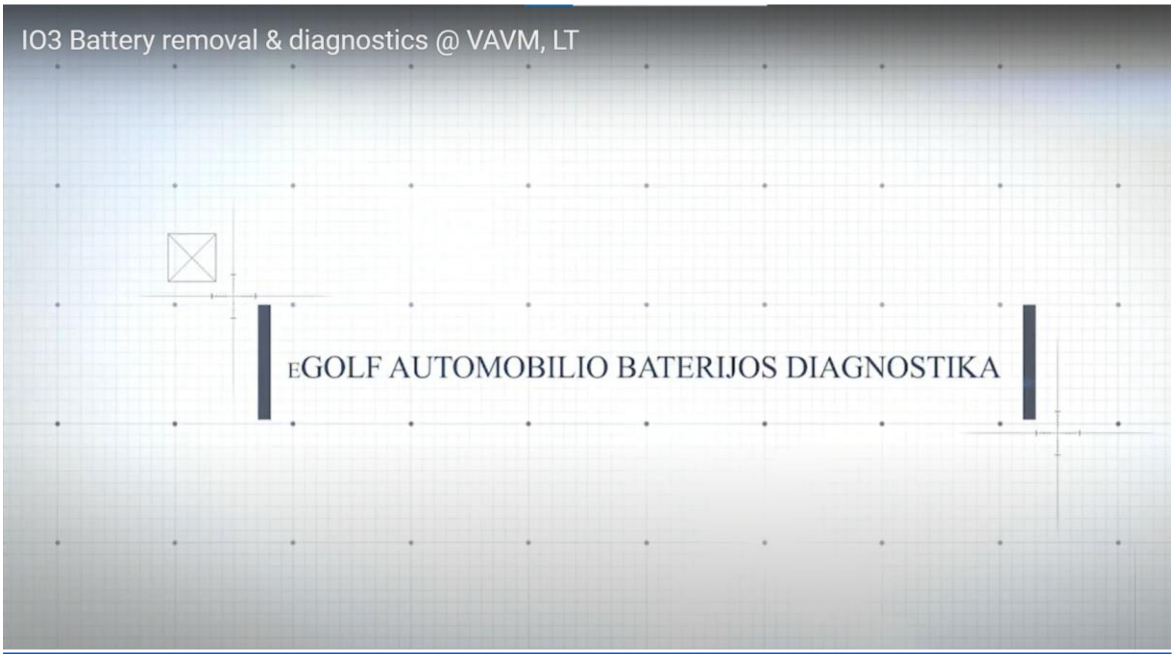


Image caption: Battery Diagnostics in a Volkswagen E-Golf Car

The video illustrates a number of different steps:

1- Quick recap about how to prepare a safe workplace wearing individual safety tools to operate on a EV/HEV

-Setting up a safety zone

-Putting an isolating bumper protection on the back of the car, close to the HV battery

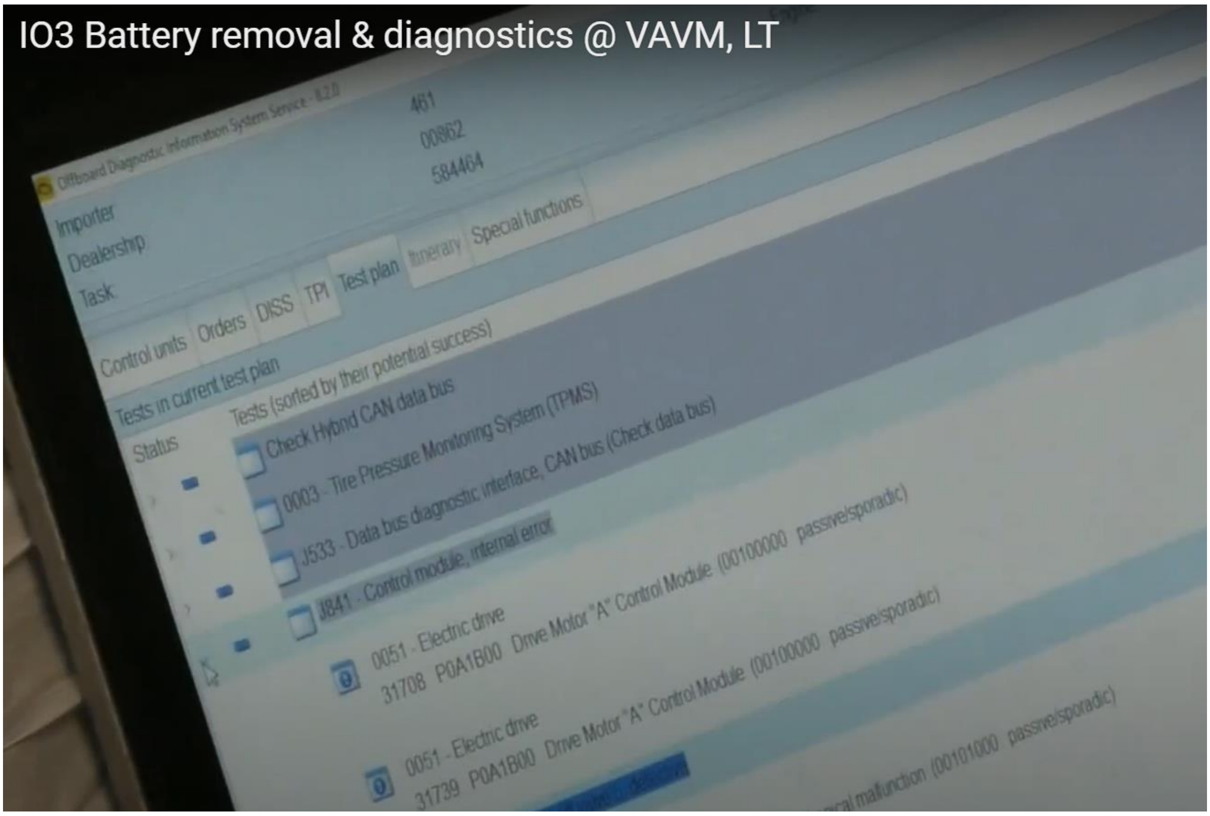
-Putting safety signs with the name of the operator working on the car

-Wearing rubber air tight gloves and protective glasses

-Removing and locking the service plug

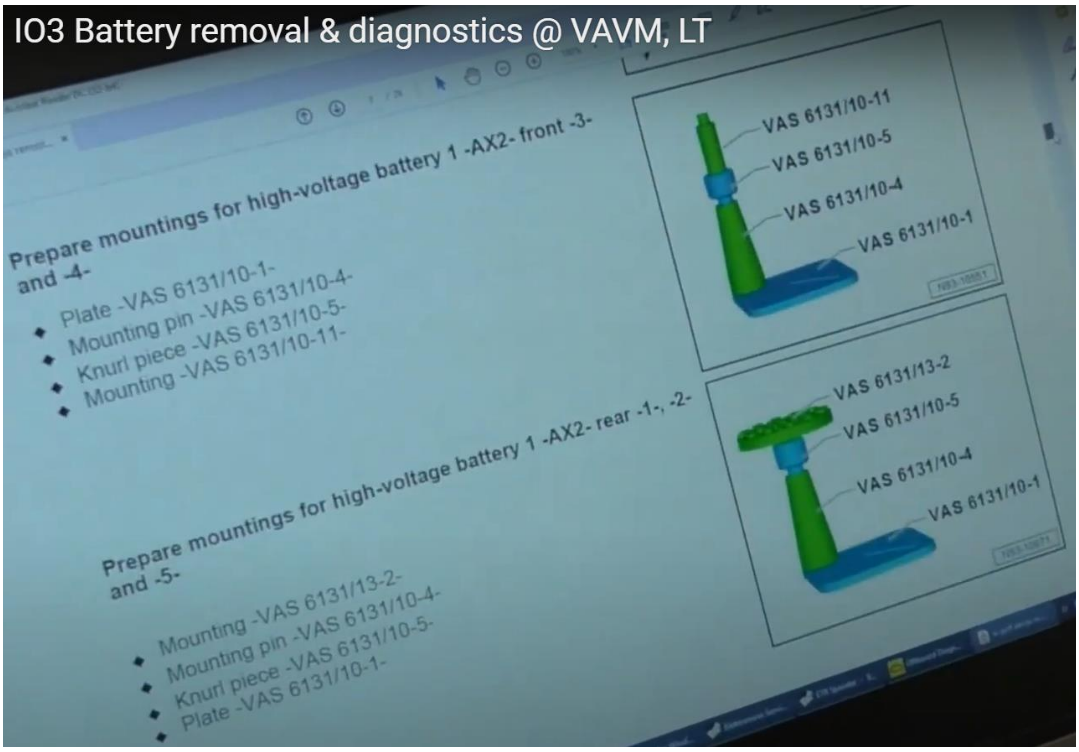
For a full recap of the safety procedure please check VAVM's Output 2 video about how to fix an EV/BEV.

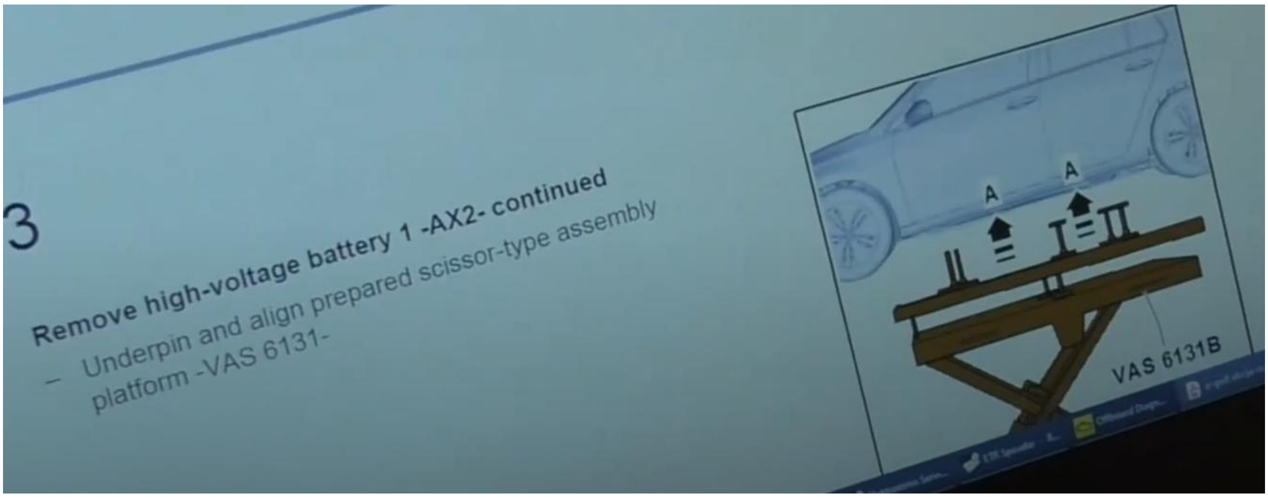
2 - Finding internal error through the OBD (Onboard diagnostic tool of the vehicle construction house): an error in the electric drive is detected.



3 - Follow the procedures contained in the vehicle's construction house documentation. Prepare the front and rear mountings for the removal of the HV battery as mandated.

First use a car elevator to lift the vehicle, disconnect HV wiring and then use a scissor-type platform to prepare for the battery removal.



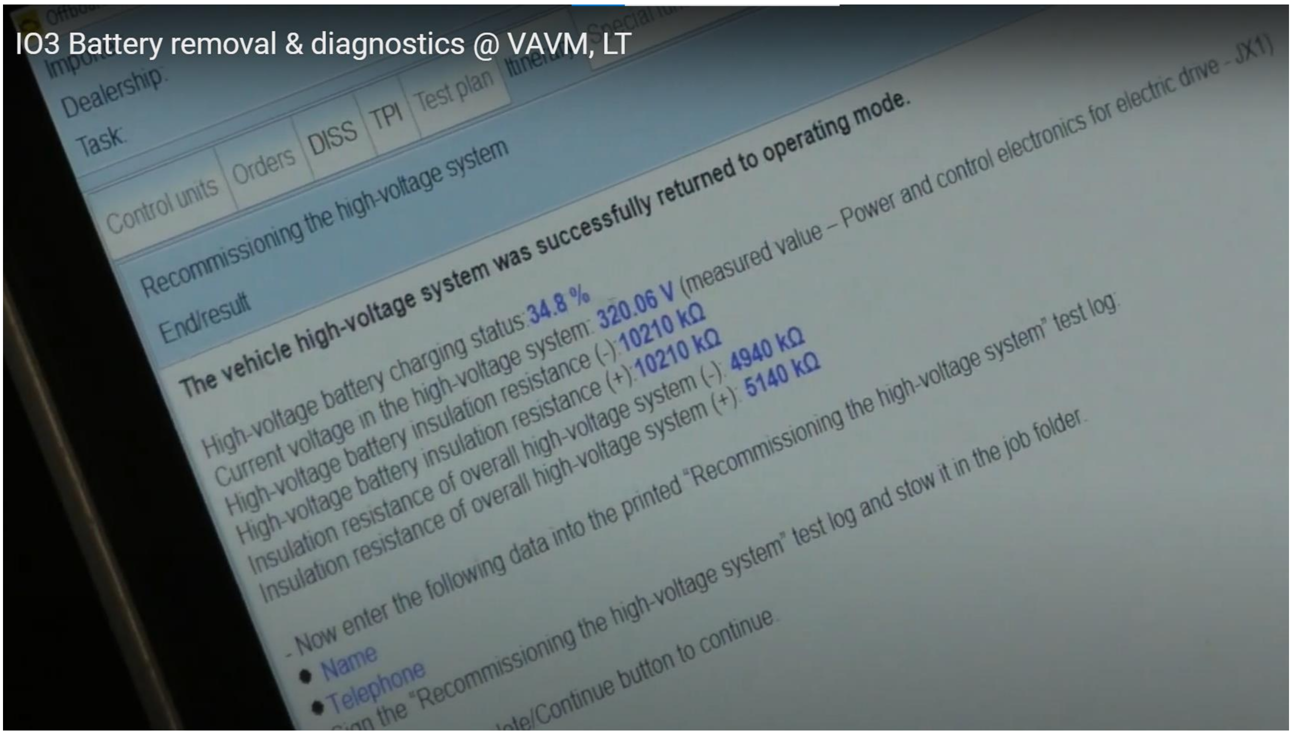


4- Now test the battery. The documentation of the construction house recommends an on-board voltage over 12V. This is to prevent damage on the HV system from low charge as well as the reduction of its life span.

To perform such operation, after HV battery removal plug electrical measurement terminals into the battery sockets, and connect a multimeter to check the total voltage. Overall onboard voltage is now 24 V.

After measuring the internal voltage, proceed to apply insulating foam onto the battery sides and then wax the external battery case. Finally, follow the reverse procedure explained above to reassembly the HV battery onto the car.

At the end, check the OBD (Onboard diagnostic tool) interface to make sure all errors have been cleared and that the high voltage battery status is ok.



EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes	Achieved
How to make the procedure easier	Learning by the video guide before performing the real test.
How to make procedure harder	Letting students check for any voltage leaks with technical documentation guidance only, without showing the procedures by example.
Expected results	Achieved
Potential Improvements	It is possible to have multiple "dummies" for HV batteries. In that way more students could learn opening/closing/checking HV battery leaks

Entry level knowledge and skills of the students What is missing	Partly adequate level to engage in the experimentation. Multi-brand diagnostic software knowledge
Equipment & Tools	Used properly
Supervision & Tutoring Potential Improvements	Effective Reducing the number of students in groups
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	A deeper knowledge of brand diagnostic software is useful
Further examples of topic-related troubleshooting problems	
EQF level 3	Charging/discharging HV system
EQF level 4	Checking HV battery leaks
EQF level 5	Checking HV battery control units inside HV battery

Option 3 - AC/DC inverter unit operations on an hybrid car

Such a program was run by the EQF 5 level courses within the Fondazione ITS Maker, based in Bologna, training Higher Technicians in advanced technology, mechatronics and automotive fields.

Within IG2 project implementation, there are namely two courses with e-mobility related contents:

- Higher Technician in Hybrid, Electric and Endothermic Engines (EQF 5)
- Higher Technician in Electric & Connected Car and Assisted Driving (EQF 5)

Since both profiles envisage high specialisation standards, attainable with a tertiary education course after the general upper secondary certificate (EQF 4), the current IO2 program is only targeting VET learners with prior knowledge and skills about:

- Electrical schemes of vehicle circuits
- Electrical and electronic technologies and applications
- Installation and maintenance technologies and techniques

The previous task run by the Fondazione ITS Maker's course in hybrid, electric and endothermic engines (see previous IO2) was about diagnosis and replacement of the output protection fuse to the auxiliary battery.

Current IO3 task: disassembly and assembly of AC/DC inverter board

Technical features: Technical features: AC/DC inverter unit installed on liquid-cooled DS vehicle. Its function is recharging the HV battery pack from the external power supply.

DESIGN FORM	
Task	***Disassembly and assembly of AC/DC inverter board***
Learning Objectives	Knowledge of the main components that run hybrid and electric vehicles in order to carry out maintenance work
Entry Level Knowledge (Theoretical)	Principles of electronics, electrotechnics, chemistry and IT
Hard Skills involved	Holding a secondary education qualification or certificate in the electronics/electrotechnics sector
Soft Skills Involved	Being vigilant in the workplace, having a responsible attitude when performing a job
Activities & Procedures required at EQF level (forecast)	Accurate assembly of electrical and electronic components
Equipment & Tools to be used	Electrical measurement equipment and traditional tools such as wrenches and screwdrivers
Other Professional Roles involved	EiP teacher (electrically instructed person)
Supervision & Tutoring Activities	Correct use of individual protection tools and correct execution of the steps as mandated in the technical data sheets
Expected Results / Solution	Correct assembly of all the components involved

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:

Procedure

1. Inverter control

Safety:

-before starting, wear the necessary protective equipment

-check that there is no residual current in the circuit

-the voltmeter must read zero

2. Removing the board

-Using a screwdriver, remove the board connector

-Unscrew the 4 screws in the corners of the circuit board with the screwdriver

-Using a screwdriver, remove the board connector

-Remove the board to check the correct assembly of the components underneath

3. Reassembly

-Reconnect the board after verification

-Use a screwdriver to tighten the 4 board fixing screws

-Check the operation of the fuse with the voltmeter

4. High-voltage cable connection

-Unscrew the two outer screws and the two inner screws with a socket spanner

-Disconnect the cable

Safety: mandatory point prevents accidental polarity reversal.

-Insert the cable and check that the cable contacts slide over the housing.

-Tighten the two internal screws and the two external screws.

EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes How to make the procedure easier	Achieved Teachers preparing the workplace and all the necessary instruments/tools in advance

How to make procedure harder	Working on different models of vehicle engines and electrical components
Expected results	Achieved
Entry level knowledge and skills of the students What is missing	Adequate level to engage in the experimentation. Diagnostic skills on vehicles
Equipment & Tools	Used properly
Supervision & Tutoring Potential Improvements	Effective Even more accurate use of safety protection tools when working with high voltage devices.
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	A deeper knowledge and skills on repair and maintenance operations
Further examples of topic-related troubleshooting problems	
EQF level 3	

EQF level 4	
EQF level 5	Procedures for the disassembly of HV engines and electrical components

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Option 4 - Performing electrical insulation on an HV vehicle.

Such a program identifies a preliminary operation that must be executed anytime an operator is performing an electrical task. Despite being a preliminary task, it should be executed only by instructed people because it involves electrical insulation.

For these reasons, at Göteborgs Tekniska College electrical insulation measurements should be performed by learners attending the e-mobility training suite, which is composed by the following units:

Module Title	Duration	Contents
EV Awareness	4 hours (theory)	● Environmental Issues & Constraints ● Market development ● Total cost of ownership ● Technology involved
Battery System Overview	8 hours (theory and practice)	● Battery Technology ● Electric Safety ● Battery Management ● Usage ● Durability
Lithium-Ion battery system	16 hours (theory and practice)	● Cell Formats ● Physical Chemistry ● Supply Chain ● System Design ● Production
EV charging and power supply	12 hours (theory and practice)	● Modes ● Behaviour ● Infrastructure ● Business Model ● Power Components
Electrical machines and transmission	16 hours (theory and practice)	● Drives overview ● Hybrid powertrain typologies ● Circuit theory

Task: performing electrical insulation measurements on an HV circuit (Volvo XC 40 Recharge car)

This task should be performed after the insulation test on the multimeter and measurement equipment is carried out, as shown in Output 2 video by Goteborg Technical College.

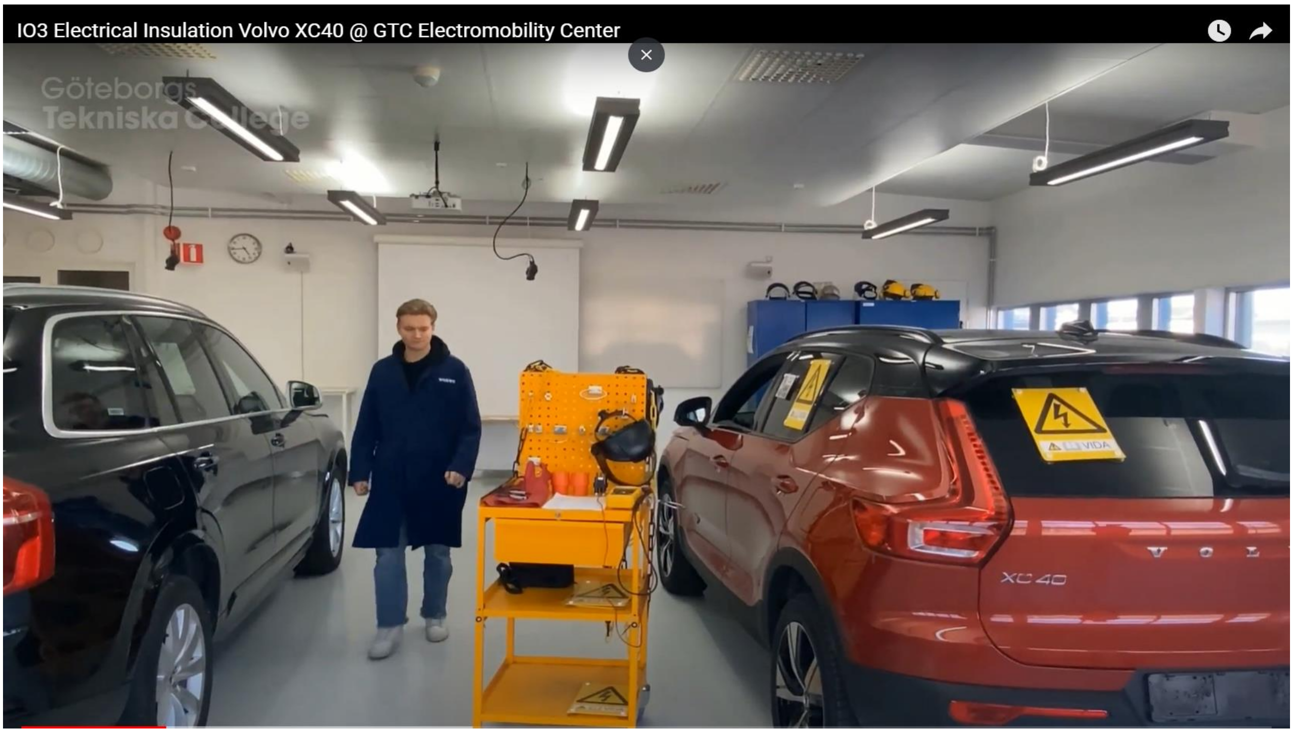
The multimeter insulation test identifies a preliminary operation that must be executed anytime an operator is performing an electrical task. Despite being a preliminary task, it should be executed only by instructed people because it involves electrical insulation.

Because of this, insulation tests on e-vehicles must be performed by an electrical instructed person too (EiP).

DESIGN FORM	
Task	***Insulation test on an electric vehicle***
Learning Objectives	Knowledge of procedures to properly and safely test the electric vehicle with diagnostic tools
Entry Level Knowledge (Theoretical)	EQF level 3
Hard Skills involved	The electric system DC Voltage Operating the equipment involved for measuring Connecting and disconnecting in a safe manner BECM (Battery Energy Control Module) Awareness components
Soft Skills Involved	Communicating to team members Understanding manuals

Equipment & Tools to be used	HV-insulation tester Test adapter Adapter EU Special equipments
Other Professional Roles involved	EV responsible employee
Supervision & Tutoring Activities	The EV responsible employee supervision and guiding through the steps of the training activity
Expected Results / Solution	The isolation measurements completed correctly

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:



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Innovation
Garage of Garages

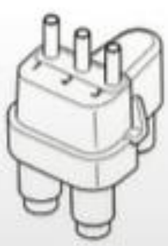
Step 1: insulation measurement for high voltage systems

Modell	År	Motor	Växellåda
XC40	2022	E400V2	1EDT FWD

Isolationsmätning högvoltsystem

Operationsnummer: 31133-3

Isolationsmätning högvoltsystem

Specialverktyg	
	**951 3038 ISOLATIONSTESTARE** **Verktygsnummer:** 951 3038 **Verktygsbeskrivning:** ISOLATIONSTESTARE **Verktygstavlor:** EU99
	**951 3048 TESTADAPTER** **Verktygsnummer:** 951 3048 **Verktygsbeskrivning:** TESTADAPTER **Verktygstavlor:** EU99
	**951 3047 TESTADAPTER** **Verktygsnummer:** 951 3047 **Verktygsbeskrivning:** TESTADAPTER **Verktygstavlor:** EU99
	**951 3167 ADAPTER EU** **Verktygsnummer:** 951 3167 **Verktygsbeskrivning:** ADAPTER EU **Verktygstavlor:** 39

Step 2: insulation measurement for high voltage systems

Warning: only specially trained technicians may work with high voltage systems

#Measurement 1

- Perform insulation test in one go
- Diagnostics / components / controllers / Battery Energy Control Module (BECM) / Diagnostic sequences / Insulation test on high voltage systems

Tips: when a contactor changes position there is a clicking sound from the high voltage cabinet.

#Measurement 2

Warning!

Function K**Ω** may be missing on 951 3038. If this is the case, use a multimeter for this step.

Warning!

Select the multimeter as shown in the picture.

Copy the measuring instrument as shown in the picture

Use the special tool 951 3038. Use the special tool 951 3048.

Resistance measurement between socket 1 and socket 2.

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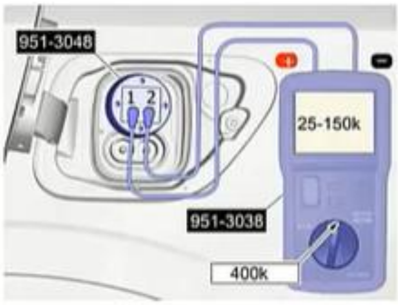
Modell	År	Motor	Växellåda
XC40	2022	E400V2	1EDT FWD



Obs!

Funktionen kΩ kan saknas på er 951 3038. Om så ar fallet anvand en multimeter för detta steg.

Obs!

Välj matområde enligt bild.

Koppla in mätinstrumentet enligt bild.

ⓒImage is property of Volvo Group

#Measurement 3

Important!

Perform the insulation measurement with 500V.

Important!

When performing isolation measurement , keep the button pressed for at least 5 seconds so that the supply wire stabilises.

Isolation measurement between socket 1 and socket 2.

Use the special tool 951 3038. Use special tool 951 3167

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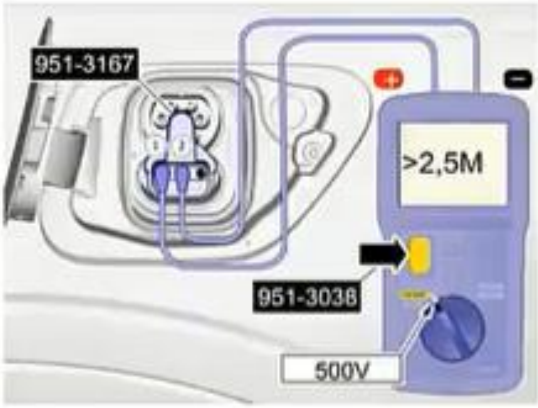
Modell	År	Motor	Växellåda
XC40	2022	E400V2	1EDT FWD



Viktigt!

Utför isolationsmätning med 500 V.

Viktigt!

Vid isolationsmätning, håll knappen nedtryckt i minst 5 sekunder så att mätvärdet stabiliserar sig.

Isolationsmätning mellan uttag 1 och uttag 2.

Använd specialverktyg: 951 3038 Använd specialverktyg: 951 3167

Ⓒ Image is property of Volvo Group

EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes	Achieved
How to make the procedure easier	Limit testing to selected areas and not performing the full check
How to make procedure harder	Adding more parts to the measurements and BECM too (Battery Energy Control Module)

Expected results	Achieved
Entry level knowledge and skills of the students	Adequate level to engage in the experimentation.
What could be improved	Depending on the students level of previous courses, electrical safety and regulations (EQF 3-4) concerning the actual tasks as well as the country and EU laws
Equipment & Tools	Used properly
Supervision & Tutoring	Effective
Remarks about students' attention	It is not an option for students not to pay attention. HV regulations are imperative for safety reasons.
Potential Improvements	As always, communication between students and tutor regarding HV safety applies in all above cases and has a constant aim for improvement (5s and Lean)
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	Depending on level of training (EQF 3 or 4) more HV safety courses apply

Option 5 - Performing electrical diagnosis on a EV/HEV through OBD software

Such tasks were performed by students attending the technical and vocational courses (EQF 4) at IIS "A. Ferrari" in Maranello (Modena, Italy).

Based on the learning objectives of the project - getting students familiar with the electric and hybrid vehicles, batteries and engines, the following study courses were identified as most suitable to run IG2 project's experimentation:

- Maintenance and Technical Assistance (EQF 4)
- Technician for the Construction of Transportation Means - Road Vehicles (EQF 4)

At such a level students attend mandatory work safety courses - both general safety recommendation at work and specific mechanic and electrical risk training, but, given their young age, they are not usually trained as EiP (electrically instructed person) and they cannot work with high voltage batteries or circuits. Because of those restrictions, it is not possible to have students work at power circuits, electrical insulation of EV/HEV, at HV batteries or at e-vehicle charging or de-charging.

On the other hand, electrical diagnostic tools such as, in this example, Texa Edu Axone Nemo2 software, are suitable for specific didactic or training purposes to manage control units of cars.

Multi-environment OBDs (on-board diagnostic tools) allow VET teachers to train both learners and workers to operate diagnosis on HEV/EV or ICE cars.

Diagnostic operations can be about:

- engine parameters
- battery parameters
- control unit scans
- electrical schemes
- emission analysis
- lights settings
- brake pads efficiency & wear control

Task: Performing engine diagnostic and troubleshooting operations on an hybrid vehicle

Through the use of an OBD (on-board diagnostic tool), teachers will simulate parameter errors in the battery or malfunctions in the control unit of an hybrid vehicle. Learners will participate in the lesson by making hypotheses on the failure analysis and troubleshooting options.

DESIGN FORM	
Task	***Engine failure analysis and troubleshooting on an hybrid vehicle***
Learning Objectives	Correct interpretation of the electrical / electronical signals from the control unit of the vehicle
Entry Level Knowledge (Theoretical)	Basic knowledge of electronics and electrotechnics
Hard Skills involved	Knowledge of the components and working mechanism of an automotive engine
Soft Skills Involved	Autonomy and ability to plan and execute troubleshooting procedures
Activities and procedure required	Advanced diagnostic activities (either simulated or performed by the EiP teachers)
Equipment & Tools to be used	OBD (on-board diagnostic tool)
Other Professional Roles involved	EiP teacher (electrically instructed person) with automotive diagnostics skills
Supervision & Tutoring Activities	Teacher of Mechanics / Electronics
Expected Results / Solution	Correct interpretation of signals from the control unit of an automotive hybrid engine

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:

Step 1 - simulating errors that might occur in the ECU

The error is simulated by physically disconnecting the connector and the temperature pressure sensor. Now the OBD screen detects no signal, exactly as if the circuit was broken.

Step 2 - managing the OBD interface

OBD is the last generation panel to manage communication between the vehicle and the operator. By plugging the connector into the OBD port, with the car ignition on, it is possible to communicate with the car system through the screen interface. Where is the OBD socket? the OBD socket is on the lower left-hand side of the cockpit

Step 3 - getting to know the car registration papers

It is very important that learners are familiar with the Vehicle Registration Certificate and all the mandatory information contained therein.

There are 3 search methods to identify the car: VIN code search, engine code search and number plate search.

The VIN code is a unique identification code for any vehicle. It is stamped on the windscreen or on the side of the door, but it's also visible on the registration.

The engine code is located at the letter P5 in the car registration papers.

Step 4 - Control Unit Diagnostics

Let’s select the control unit of the car in the OBD interface. The monitor displays a list of errors:

- intake manifold pressure sensor signal
- intake air temperature signal
- engine control unit relay - blocked contacts

The first problem (intake manifold pressure sensor signal) means that the system cannot read the pressure. The OBD screen is also returning code P0107: P stands for "power", so this is the engine code classification

The second error (intake air temperature signal) displays code P0110, that means open circuit or short-circuit to positive. It's like there was a sheared wire, and that's likely because as the engine overheats, the engine heats up too, the liners heat up as well then they also often cool down quickly. Such an hot/cold heat exchange also hardens the materials

EVALUATION FORM	
VET Teachers & Trainers	
Learning Outcomes How to make the procedure easier	Achieved

How to make procedure harder	Increasing time for practical exercises to become familiar with the diagnostic tools Preparing internal battery faults
Expected results	Achieved
Entry level knowledge and skills of the students What is missing	Adequate level to engage in the experimentation. EV/HEV safety rules and operating procedures. Advanced knowledge of OBD port tools.
Equipment & Tools	Used properly
Supervision & Tutoring Potential Improvements	Effective Peer to peer didactic methods could be suggested. Reduce student number in groups
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	Expanding learning objectives simulating further potential failures.
Further examples of topic-related troubleshooting problems	

EQF level 3	Charging/discharging HV system (theoretical knowledge)
EQF level 4	Checking HV battery leaks (theoretical knowledge)
EQF level 5	Checking HV battery control units inside HV battery (theoretical knowledge)

3. Collecting VET learners' feedback

As stated in the IO1 paper about designing a pilot Train-the-Trainers program about e-mobility, a relevant part of the program itself relies into collecting the learners' feedback about both their appreciation and their self-evaluation about the training experience.

Questions might vary according to the learning objectives of the experimentation and the EQF level of the VET provider, but on a general rule the following criteria should be met in order to administer feedback questionnaires to measure the impact of the training activities:

-forms should be collected anonymously to make sure respondents are free to express their sincere and honest feedback about the training program, either on a paper or digital format;

-questions might be multiple-choice or on a scale, but, in any case, some room for further comments or remarks should be left;

-the extent to which the training workplace helped students develop e-mobility skills should be assessed;

-the effectiveness of the mentoring or supervisory activities should be assessed;

-the extent to which prior knowledge and skills were allowed learners to make the most out of the training program should be assessed;

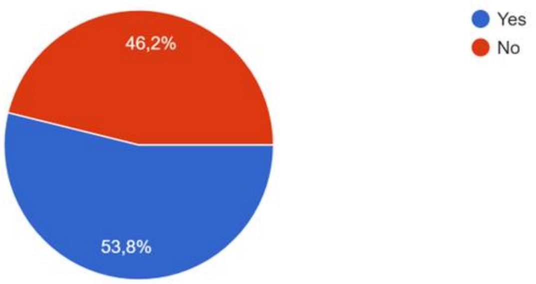
-the perception, on the learners' side, of actual development of e-mobility skills should be assessed;

-the extent to which learners think to be suitably prepared to transition to the job market.

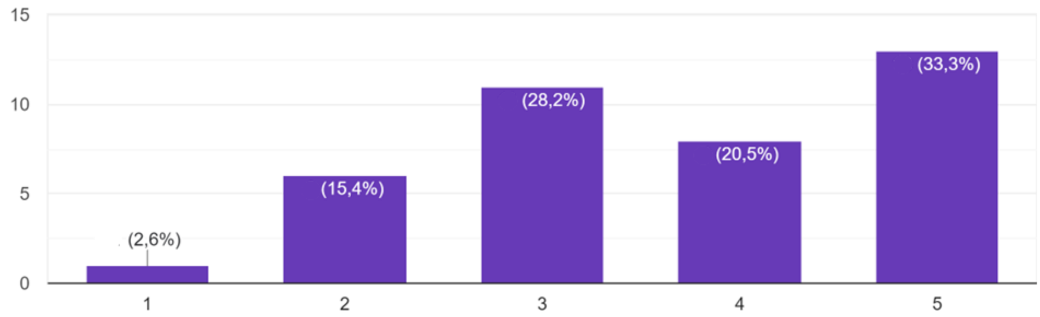
Examples of the collected feedback can be seen from the charts below, which report genderless aggregate data from all the countries and EQF levels involved.

Answers with scale from 1 to 5 mean that respondents were asked to rate the sentence in the questions with a score from 1 (absolutely not) to 5 (absolutely yes).

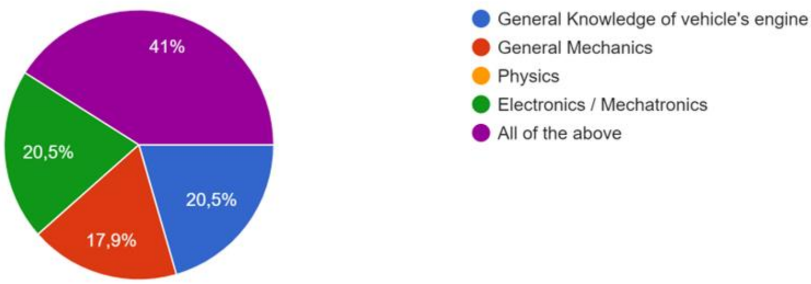
I already took classes in electro-mobility or HEV/BEV before participating in the project



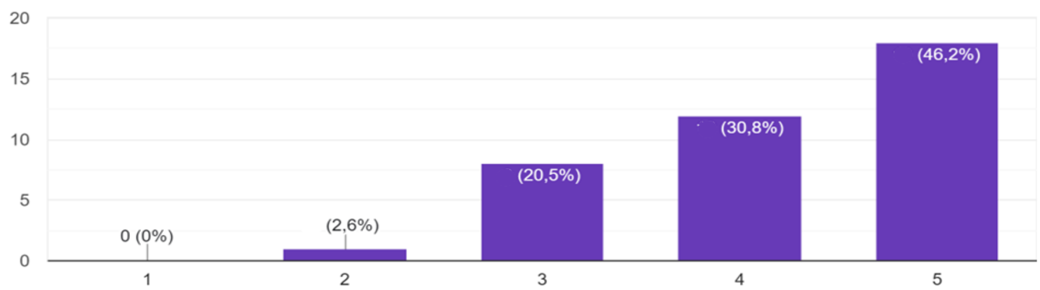
I think my previous knowledge & skills level was enough for me to take part in HEV/BEV testing



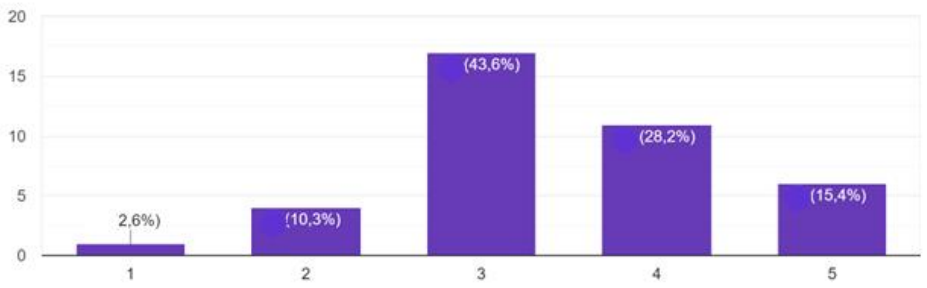
Which of the following was most helpful for you to make the most out of the HEV/BEV testing?



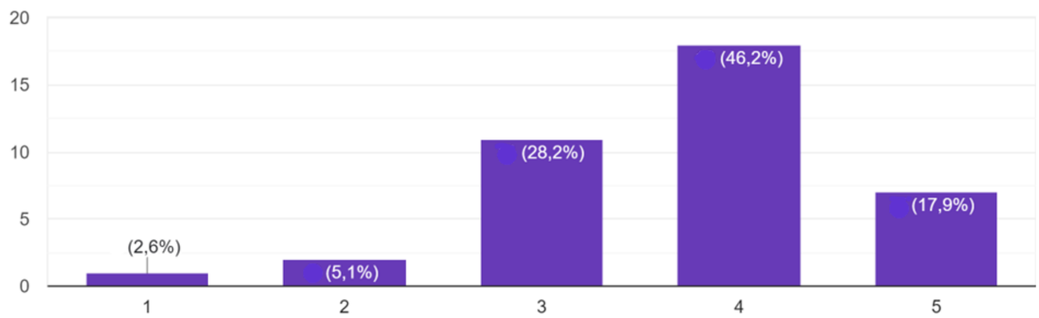
After the testing, I think I developed knowledge and skills about how a to work safely on an HEV/BEV vehicle



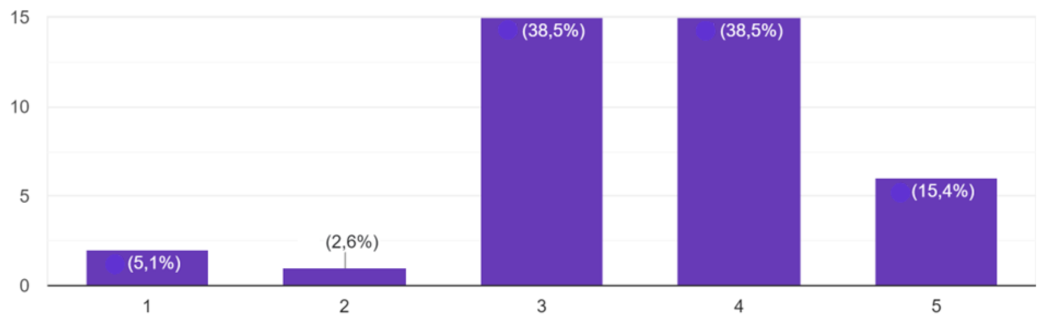
After the testing, I think I developed knowledge and skills about how to assemble & dissassemble the AC/DC inverter circuit of the car



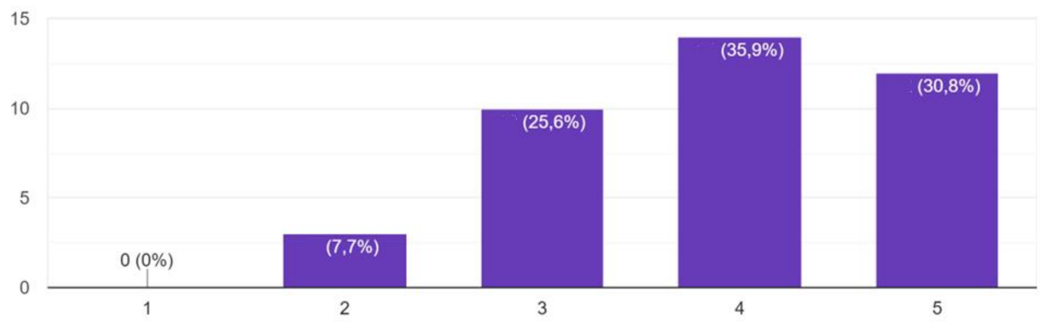
After the testing, I think I developed knowledge and skills about how to perform failure diagnosis & repair in a HEV/BEV system



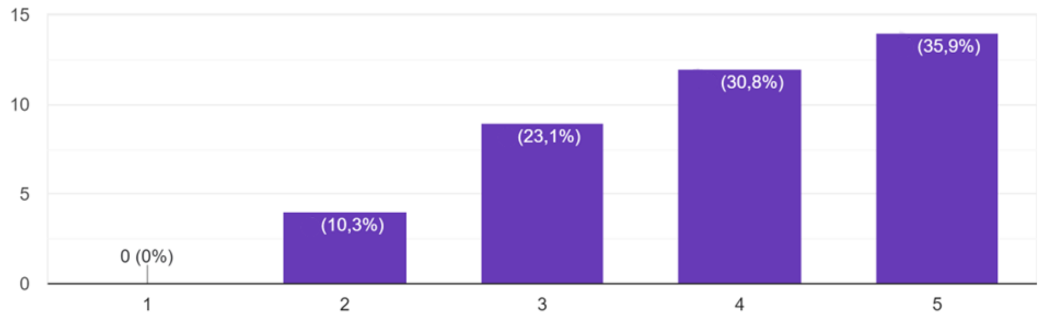
After the testing, I think I developed knowledge and skills about how to perform power unit maintenance in a HEV vehicle



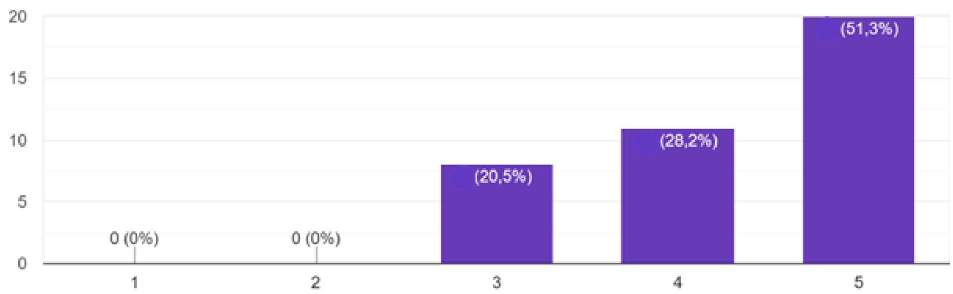
I think I am able to repeat by myself the procedures and work sequences I learned during the testing



I think I was properly trained and supervised during the testing



Thanks to the work-based learning or workplace testing, I think I am better prepared for the automotive job market



Conclusion: who is this paper for?

This paper represents the outcome of Intellectual Output 3 of “Innovation Garage of Garages” Erasmus+ project, aiming at developing green skills for the automotive sector at VET level.

The specific goal of such a paper is to provide guidelines for VET teachers and trainers willing to introduce hybrid or electric engines, high voltage and their components as a modular or integrated path within mechanics or automotive courses.

Multiple actors co-designing the training contents, the workplace layout and tools, as well as the organisational details of the didactic methodology (roles of trainers, facilitators, evaluation and assessment criteria, is the special footprint of the project. Since “Innovation Garage” is a worldwide methodology to introduce bottom-up multi-stakeholders innovation over the workplace premises, what this project is aiming at is renovating the way in which “workshops” or “garage” training is usually performed.

So, this is just a proposal that needs to be customised with specific contents according to the target learners and the regular training courses within a VET organisation.

The IO3 paper is suitable both for teachers and trainers at I-VET level (schools, training centres for young people or adults) from EQF levels 3-4, or even for H-VET at EQF 5 level (tertiary education other than university level). Nonetheless, e-mobility training can involve managers, technicians or trainers at company level - either at production houses, or repair workshops, or dealers, whenever workers need to develop or upgrade their skills about the management and maintenance of HV batteries, of HEV/EV vehicles and their components.

Project no. 2020-1-IT01-KA202-008555

"Innovation Garage of Garages"

IO4 – Intellectual Output 4

Training programme covering the installation/verification of on-board avionics, based on the work-based learning methodology located inside the innovation garage

Output Type: Open / online / digital education

OER – Open Educational Resource

The project is funded by ERASMUS+ Programme of the European Union. The content of this material does not reflect the official opinion of the European Union, the European Commission and National Agencies. Responsibility for the information and views expressed in this material lies entirely with the author(s). Project number: 2020-1-IT01-KA202-008555

Training Program on avionics circuits assembly on EV/HEV

Language: English

Author:

Innovation Garage of Garages Partnership

Coordinator: Cisita Parma scarl, Italy

Co-funded by the Erasmus+ Programme of the European Union

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Intro: the learning model

Since VET providers maintain close cooperation with the industrial sectors, especially within the automotive field, workplace training is the most valuable asset that educational institutions hold to develop job-related skills, facilitating the learners' transition into the labour market.

In this view, the "Innovation Garage of Garages" project (named "IG2" below), holds the purpose to bring VET providers and automotive companies together (either construction houses, OEMs manufacturers, dealers, car-repair workshops) to co-design training paths & learning environments suitable for the development of green mobility skills, in terms of:

a-learning goals & contents;

b-layout of the training workplace;

c-tools, machinery and equipment.

According to the panorama of the green skills and job profiles within the Automotive sector, identified in the IO1 paper, the main 5 work processes that IG2 project deals with are:

IO2: Installation & Assembly of EV/HEV engines

IO3: Maintenance of EV/HEV engines

IO4: Configuration & calibration of Avionics systems in e-vehicles

IO5: Maintenance of Avionics systems in e-vehicles

IO6: After-sales assistance & safety issues related to EVs/HEVs

The training environment should make practical learning accessible and inclusive, and students should learn from work processes and organizational structure, as well as use technological assets that are the closest possible to the real workplace layout.

This is what IG2 partnership agreed to call "situated learning", identifying the dynamics of a training environment equipped with technological tools, where learners are immersed into a productive process governed by supervisors performing a mentoring and leading role, aimed at manufacturing a given product.

The learning model inspiring the project methodology is the "Activity Theory" framework by Yrjö Engeström (1987/2015), representing the third generation of academic researchers studying the topic, after the contributions of cultural-historical psychology from the Russian Vygotsky to Leontyev.[1]

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[1] For a very introductory documentation over the "Activity Theory" system please see:

- Andy Blunden "Engeström Activity Theory and Social System", 2015

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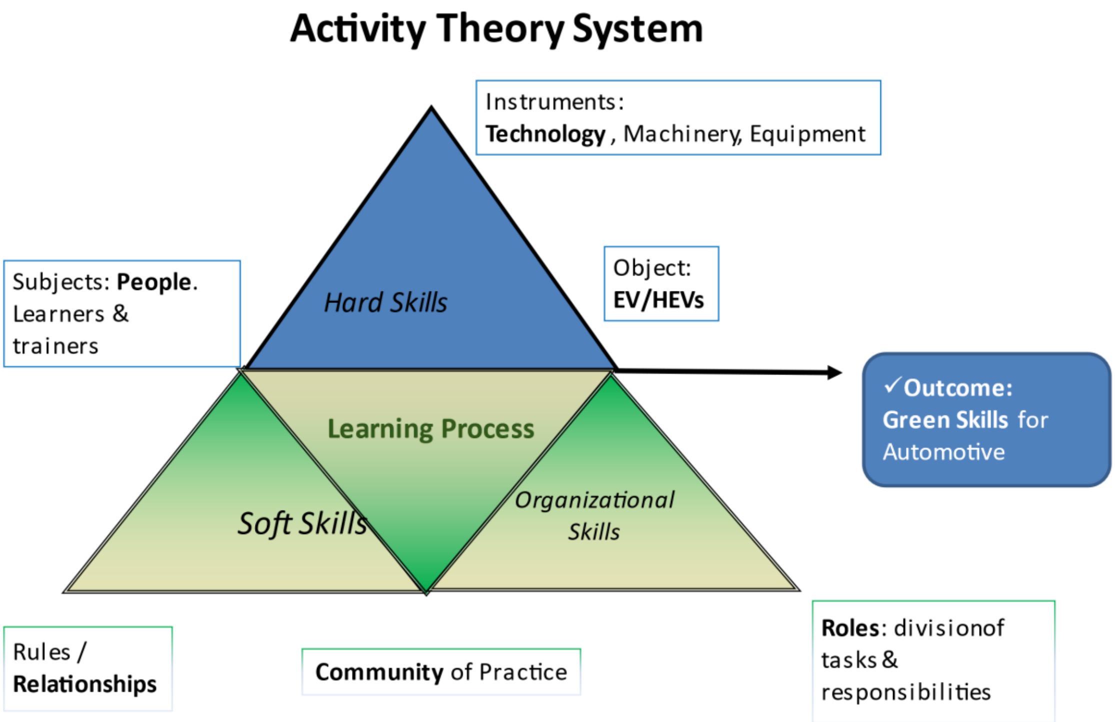

According to such model, the overall learning process is composed of two main dimensions: the immersive experience of actually doing some activity or of producing a real product within a given environment, such as the school lab or the training facility, or workplace itself. This is the dimension where the e-mobility hard skills are being developed, thanks to the interaction of 3 main elements: people (learners & trainers) as *subject* of the process; tools (such as technology, equipment and machinery) as *instruments* making the learning process come true; the *electric/hybrid vehicle* or one or more of its components, as the *object* of the learning process itself. The outcome of the interaction of such 3 elements is the expected learning goal itself for the relevant testing, or, more generally, the green skills for the automotive sector.

Underneath the upper triangle, the Activity Theory puts the hidden or intangible part of the learning process, which is related to the development of all the soft skills implied by interacting within a complex organisation of people. This is what happens to workers in a company, but workplace learning or workplace simulation actually reflects the very same dynamics. As a matter of fact, within an automotive production site or within a car repair workshop, for example, workers are assigned different roles, responsibilities and tasks which actually shape the interpersonal relationship happening over there. VET learners, either in their initial training at school, or involved in lifelong and continuous training at work, are immersed in a community of

- Oliver Ding, Yrjö Engeström: the Activity System Model, 2021

practice, where knowledge, skills & behaviours are shared, promoted, rewarded or even confuted or rejected.

IG2 project, by bringing together VET providers and companies, aims at co-designing learning experiences for the development of e-mobility skills, keeping in mind such behavioral and organizational learning model.

1. Referencing Output 4 e-mobility skills to the current job qualification frameworks

Output 4 of the IG2 project is focused on the development of skills related to the first assembly**,** installation, **calibration** and/or **configuration** of **electronic circuits (**including **high voltage batteries)** and **avionics circuits**, such as **assisted** or **autonomous drive** systems and of relevant **sub-components, into electric or hybrid vehicles.**

According to IG2 partners, such tasks can range from simple and basic ones, attainable from EQF 3 operators or even lower, e.g. C-VET operators achieving EQF2 vocational qualifications, to technical or supervisory roles (EQF 4 - EQF 5).

Output 4, outlining the train-the-trainers program for VET teachers willing to introduce e-mobility in their didactic courses, collects the job qualifications in the automotive sector according to the ESCO framework and from the job-profiles and skills card classified by the Erasmus+ Sector Skills Alliances DRIVES 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B (for the general automotive sector) & ALBATTS 612675-EPP-1-2019-1-SE-EPPKA2-SSA-B (specifically for the battery sector).

According to such classifications, Output 4 refers to the following job roles matching the EV/HEV engine assembly operations:

	DRIVES Development and Research on Innovative Vocational Education Skills	albatts
Automotive Battery Technician		Battery Manufacturing Technician
Battery Assembler		Battery Module Assembly Technician
Battery Test Technician		Battery Quality Technician
		Battery Recycling Technician
Avionics Technician	ADAS /ADF Testing & Validation Engineer	
	Sensor Fusion Expert	

	Connected Vehicles Technician	
	Automotive Cybersecurity Tester	
	Highly Automated Drive Engineer	
Electronic Equipment Assembler	Automotive Mechatronics Expert	
Electronic Equipment Inspector		
Vehicle Electronics Assembler	Robotic Technician	
	Predictive Maintenance Technician	
Microelectronics Engineering Technician	Functional Safety [Engineer/Technician]	

Among all the e-mobility related job qualifications that ESCO, DRIVES and ALBATTS put together, the one listed above are the ones that are at least partly relatable to the training programs that were designed and tested by the IG2 VET providers' consortium, and that will be described in the chapters below.

2. Designing, testing and evaluating results of training programs about the calibration of electronic or avionics circuits in EV/HEV

During the Pilot Phase of IG2 project (Output 1), partners agreed that the basic structure of any topic-specific program about e-mobility should start with a joint business-VET design phase, including:

– identifying learning objectives,

– setting knowledge or skills entry requisites for VET learners,

– identifying the work procedures to implement,

– setting the training workplace layout and necessary tools/equipment,

– deciding on the expected outcomes of the troubleshooting,

– establishing supervisory and tutoring roles

VET providers were not assigned prescriptive rules about which relevant topic should be chosen for a training program about EV/HEV engine assembly or installation. Multiple reasons usually affect the choice of the specific topic to focus on, and the following criteria should be taken into consideration while evaluating the potential options:

a) whether or not the VET provider is already including specific training modules or contents about EVs/HEVs in the institutional offer;

b) the EQF level of the training course where e-mobility should be taught or introduced for the first time;

c) the general level of technical knowledge & skills of the target learners as well as their behavioural / communication skills and/or their potential fewer opportunities profile

With regards to point a), this is absolutely the most significant and diriment criterion that should guide the choice of VET trainers: are learners already trained about safety precautions around HV batteries and electric or hybrid engines? Are learners already able to read the electrical schemes of the car? Are they already familiar with the structure and components of internal combustion engines whatsoever?

If this is case, it is probably a good choice to delve into EV/HEV engines specific topics such as electrical insulation or HV battery modules checks, or calibration of ADAS systems, on-board cameras and radars. On the opposite side, learners who are not trained about electrical risks must never work hands-on with HV batteries. This happens with upper secondary education courses at EQF 3 or EQF 4 levels, where students work just on the mechanical part of engines. In this case, in the first place mandatory electrical safety courses must be attended from students, and demo classes about HV batteries where trainers show the correct

battery management procedures without students being involved, or using electronical panels simulating the engine mechanism or the switches of sensors regulating the circuits of the car, are good examples of introductory activities.

Furthermore, VET trainers should take into consideration the general profile of the target learners involved:

-EQF level of the training course and previous knowledge & skills gained by students

-the age of the learners: is it young people in initial learning or is it workers engaged in an upskilling or re-skilling course within C-VET training paths?

-the general lifelong background of the students involved: is there any type of potential disadvantage represented in the learning group?

This might range from physical or cognitive disabilities, to migrant background or language barriers preventing students from a full exploitation of the learning opportunities, or even age barriers, in the case of underqualified over-50 workers in need of a skill upscale to prevent job loss. In any of such cases, special arrangements should be envisaged by trainers in order to choose the most inclusive and barrier-free training environment possible. In case any learner has a physical disability, the workplace should be designed in a way that the learner is safe throughout the testing, yet he or she can either see the work procedures or operate some of them according to both the work safety procedures and to what the medical conditions allow. In case the learner has a mild cognitive disability, VET trainers should design the experimentation assigning tasks to small students' teams with an appointed leader with a distributed share of duties, so that everybody can be involved in the experimentation with different level of difficulty or responsibilities.

Team work and practical learning is especially recommended and effective in case of migrant learners with little command of the local language, as graphic or synthetic work procedures help understand topics or tasks quicker than a theoretical frontal class.

Evaluation. As a part of O1 train-the-trainer program results, IG2 project partners established a protocol for the evaluation of the work-based testing, to assess to which extent the program itself was successful for VET learners to develop e-mobility skills. Such assessment is a simple form with questions addressed both to VET teachers or trainers, and to business technicians, since the workplace training should be co-designed on both parts.

Teachers or trainers should assess:

– whether or not the learning goals have been met,

– whether or not the work-based testing delivered the expected outcomes,

– to which extent the expected knowledge and skills have been gained by the students or not,

– whether or not the diagnostic tools were used properly,

– whether or not the supervisory and tutoring activities were adequate to provide learners with the guidance they needed.

When relevant, teachers might also provide additional information about the main difficulties overcome, which tasks were missing or not correctly performed during the experimentation, as well as suggestions on how potentially making the experimentation easier or harder according to the learners' profiles.

On the other hand, business technicians should assess to which extent the knowledge and skills that students developed thanks to such a training experience are indeed useful and transferable to the job market. Furthermore, business technicians might as well provide further examples of troubleshooting and diagnostics experimentations on similar topics, that they believe might help learners develop missing skills about working on EVs/HEVs at different EQF levels.

Let's see examples of the training programs that each country team participating in IG2 project designed & tested.

Option 1 – Theoretical introduction on ADAS systems at IIS A. Ferrari, Maranello, Italy (EQF 3-4 levels)

Such tasks were performed by students attending the technical and vocational courses (EQF 4) at IIS "A. Ferrari" in Maranello (Modena, Italy).

Based on the learning objectives of the project - getting students familiar with the electric and hybrid vehicles, batteries and engines, the following study courses were identified as most suitable to run IG2 project's experimentation:

- Maintenance and Technical Assistance (EQF 4)
- Technician for the Construction of Transportation Means - Road Vehicles (EQF 4)

At such a level students attend mandatory work safety courses - both general safety recommendation at work and specific mechanic and electrical risk training, but, given their young age, they are not usually trained as EiP (electrically instructed person) and they cannot work with high voltage batteries or circuits.

Nonetheless, it is possible to introduce theoretical knowledge about what ADAS is, its main functions and technology and the relevant European and national legislations. At this level, it might be also possible to to have students work at the calibration of real electronic systems like ADAS, provided that no electrical voltage is on.

ADAS is an acronym standing for Advanced Driver Assistance System, envisaging 6 different levels of automation, ranging from no assistance whatsoever to complete autonomous drive – not currently legal in Europe.

According to the definition of the European Union[2], ADAS in known as a "*vehicle-based intelligent safety system which could improve road safety in terms of crash avoidance, crash severity mitigation and protection, and automatic post-crash notification of collision; or indeed as integrated in-vehicle or infrastructure-based systems which contribute to some or all of these crash phases. More generally, some driver support systems are intended to improve safety whereas others are convenience functions*".

Students were assigned the task to simulate, thanks to a digital learning environment, potential risks involving at least two vehicles on the road - for example a sudden obstacle on the lane, a car not giving way when turning left, or late or poor car braking in case of emergency. In all such situations, ADAS systems offer extra help and assistance to the driver, through the lane assist and lane camera functions, preventing fatal crashes and injuries.

DESIGN FORM	
Task	***Finding out & simulating the safety functions of ADAS systems***
Learning Objectives	Getting to know when ADAS systems may help drivers managing the vehicle in emergency situation on the road
Entry Level Knowledge (Theoretical)	Able to recognize electronics/avionics components (ADAS systems)
Hard Skills involved	Able to operate with an OBD (Onboard diagnostic tool)
Soft Skills Involved	Able to read and understand procedures in workshop manuals and diagnostic tools. English language
Activities & Procedure required at EQF level (forecast)	III Level

[2] European Commission's "Advanced Driver Assisted Systems" 2018 by ERSO, European Road Safety Observatory.

Equipment & Tools to be used	OBD dealership software.
Other Professional Roles involved	VET trainer or workshop manager
Supervision & Tutoring Activities	Theoretical explanation of avionics systems
Expected Results / Solution	Students will know how to identify ADAS components and to understand how ADAS systems take control of the vehicle in an emergency situation

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:

Educational and training materials about the EU legislation regulating ADAS systems and its functionalities are stored as open didactic materials on IG2 Google Drive Folder (Italian language only).

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EVALUATION FORM		
Students' performance		
Students were engaged and interested	YES	Students were assigned the task of researching the matter and illustrating it to teachers and fellow peers, thus resulting in more individual responsibility and commitment
Students were able to apply theoretical knowledge to practical tasks	NA	Theoretical training only
Students were able to perform tasks	NA	Theoretical training only
Students were able to work autonomously	In part	With some guidance from the teachers about the ADAS topics to research
Students were able to find faults	NA	Theoretical training only
Students were able to identify safety procedures	YES	Students understood the safety rules and law regulations about ADAS systems
Students were able to use diagnostic tool	In part	With some guidance from the teachers about the dealers' OBD tools (onboard diagnostic tools)

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	Achieved
Entry level knowledge and skills of the students	Adequate level of self study
Equipment & Tools	Adequate level of awareness
Supervision & Tutoring	Effective
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	Practice on finding faults in ADAS systems
Missing skills for students:	Knowledge of organizational / business roles
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ Deeper or up-to-date knowledge of software or diagnostic tools

Further examples of topic-related troubleshooting problems	
EQF level 3	-
EQF level 4	-
EQF level 5	-

Option 2 – Calibrating ADAS systems of e-vehicles using a calibration framework at ROC Midden Nederland

The training program was designed & tested by ROC Midden Nederland (VET provider) and Innovam (company), and is targeting VET students attending the following courses:

- First Car Technician (EQF 3)
- First Truck Technician (EQF 3)
- Technical Specialist Car Technology (EQF 4)
- Technical Specialist Truck Technology (EQF 4)

All of them already include, in the regular training paths, teaching contents about the following units:

- Hybrid and electrical drivetrain
- Electric engines
- NEN9140 (EU regulation about electrical works)
- Charging Systems
- Inverter/Converter Battery Management

Nonetheless, the program might be optionable even for trainers with no previous hands-on or theoretical classes about EV/HEV engines, when used as an introductory unit about infotainment and connectivity systems currently included in vehicles. Indeed no high-voltage battery is involved in the calibration of ADAS systems such as radars, front camera and lane camera. For further details about electrical safety when dealing with e-vehicles, ROC Midden Nederland and Innovam do include such topics in a short one-day modular course for students and workers called "Safe working on e-vehicles basics" (see Output 1), as well as in de-energization of HV battery described in Output 2 and Output 3 of the IG2 project.

DESIGN FORM	
Task	**ADAS calibration**
Learning Objectives	Getting to know when static calibration of ADAS components is needed. Being able to perform a static calibration on an ADAS component (camera or radar).

Entry Level Knowledge (Theoretical)	EQF level 3. Being able to recognize ADAS components. Knowledge about how ADAS systems work. Knowledge about 4-wheel alignment procedures.
Hard Skills involved	Being able to operate a diagnostic tool. Being able to perform 4-wheel alignment. Being able to use ADAS calibration equipment.
Soft Skills Involved	Being able to read and understand procedures in workshop manuals and diagnostic tools. Being able to work in a precise and accurate way.
Activities & Procedure required at EQF level (forecast)	4-wheel alignment if needed Reed and erase DTCs (diagnostic trouble codes) Set-up ADAS calibration equipment
Equipment & Tools to be used	Diagnostic tool ADAS calibration tool
Other Professional Roles involved	Workshop manager who is responsible for safety. He has to check if calibration is done correctly.
Supervision & Tutoring Activities	Theoretical explanation of ADAS systems. Hands-on explanation of Calibration tool. Guiding students during execution of the calibration.
Expected Results / Solution	ADAS calibration is performed correctly and vehicle is safe to drive in.

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:

ADAS Calibration course for level 4 students of ROCMN Automotive college

Procedure to introduce theoretical and practical training about ADAS systems as shown in the video:

-teacher-led introductory lesson about ADAS systems and their calibration frame and tools according to the vehicle manufacturer;

-teacher-led introduction about the static and dynamic calibration methods;

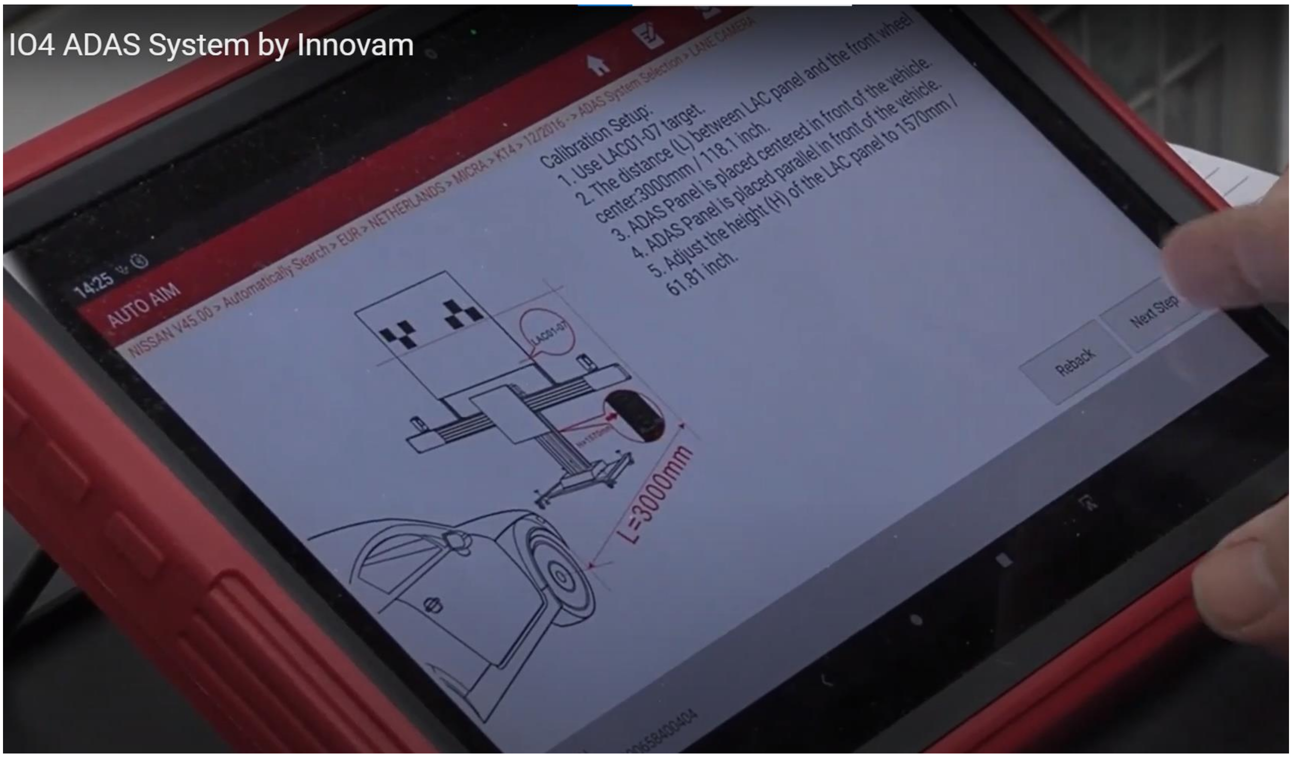
-student-led identification of the most common ADAS systems: radar, blindspot cameras, front camera and lane assist;

-student-led front radar calibration of an hybrid Suzuki Swift;

-student-led measurement of the front wheel height to ensure optimal calibration of the onboard cameras;

-student-led adaptive cruise control camera calibration of an hybrid Nissan Micra;

-student-led adaptive cruise control camera calibration and 360° degrees camera calibration of an AUDI A4;



The Nissan dealer's OBD (onboard diagnostic tool) is needed to perform the calibration set-up on an hybrid Micra model

EVALUATION FORM

Students' Performance		
Students were engaged and interested	YES	*Remarks: Students had prior knowledge about ADAS through self-study*
Students were able to apply theoretical knowledge to practical tasks	YES	
Students were able to perform task	YES	*Remarks: guided instruction from the trainers was needed*
Students were able to work autonomously	In part	
Students were aware of safety procedures	YES	*Safety shoes only*
Students were able to use diagnostic tools	YES	*Official dealer's diagnostic tools*

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	Achieved

Entry level knowledge and skills of the students	Adequate level to engage in the experimentation thanks to self-study beforehand
Equipment & Tools	Used properly
Supervision & Tutoring	Effective *Remarks: Students were very eager to learn and listened carefully to the tips of the trainer. At this point in this training no points for improvement to indicate*
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	Practice on finding faults in ADAS systems
Missing skills for students:	Knowledge of organizational / business roles
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ Deeper or up-to-date knowledge of software or diagnostic tools
Further examples of topic-related troubleshooting problems	
EQF level 3	-

EQF level 4	-
EQF level 5	-

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Option 3 – Battery Cell Information at Göteborgs Tekniska College, Sweden

This program trains learners to derive information about the state of charge of the HV battery from the dealer's OBD – onboard diagnostic tool.

Through the OBD interface, the operator is able to understand the general state of health of the lithium-ion cells composing the HV battery, as well as to interpret the data flowing from the battery cells to the driver information module.

According to the E-mobility training suite available at Göteborgs Tekniska College, such topics might be tackled in the "Battery System Overview" as well as in the "Lithium-Ion Battery" modules.

Module Title	Duration	Contents
EV Awareness	4 hours (theory)	• Environmental Issues & Constraints • Market development • Total cost of ownership • Technology involved
Battery System Overview	8 hours (theory and practice)	• Battery Technology • Electric Safety • Battery Management • Usage • Durability
Lithium-Ion battery system	16 hours (theory and practice)	• Cell Formats • Physical Chemistry • Supply Chain • System Design • Production
EV charging and power supply	12 hours (theory and practice)	• Modes • Behaviour • Infrastructure • Business Model • Power Components

Electrical machines and transmission	16 hours (theory and practice)	● Drives overview ● Hybrid powertrain typologies ● Circuit theory

Task: Deriving data about the EV state of charge – information from cells to Driver Information module.

The operations described in such procedure do not involve hand-on work on HV battery or lithium-ion cells, in fact the task is about obtaining information about the percentage of charge of the battery and the residual autonomy of the vehicle. Because of this, such procedure might be suitable even for EQF 3 level trainees who did not achieve the qualification of EiP (electrically instructed person).

Theoretical focus – High voltage battery, cells and cell module voltage / SoC overview:

The dealer's OBD tool tests and displays the present voltage and state of charge (SoC) of all battery cell in the high voltage battery.

The high voltage battery contains 24 cell modules with either 4 or 12 cells in each module. These cells are connected to form 4 logical cells per module. The voltage for each logical cell can be read out.

The high voltage battery also contains eight cell voltage and temperature nodes (CVTN). Each CVTN handle three cell modules, i.e. 12 logical cells.

The tool can also show a cell module view, containing the cell module voltage as a sum of all logical cells in that module, and the cell module SoC as an average of the SoC of the included cells.

The tool can be used to distinguish a battery cell problem from problems related to any of the CVTNs.

- When a cell balance related DTC (diagnostic trouble code) is set and one specific cell has significantly lower voltage compared to all other cells, this could indicate a cell problem.
- When several adjacent cells or all cells for a specific CVTN deviate from the rest of the cells, this may indicate a problem with that CVTN.

Cell voltage / SoC

- Cell voltage: the voltage of the logical cell
- Cell SoC: the state of charge of the logical cell
- Cell delta voltage: the difference in voltage when comparing the cells with the highest and lowest value
- Cell delta SoC: the difference in SoC when comparing the cells with the highest and lowest value

Cell module voltage/ SoC

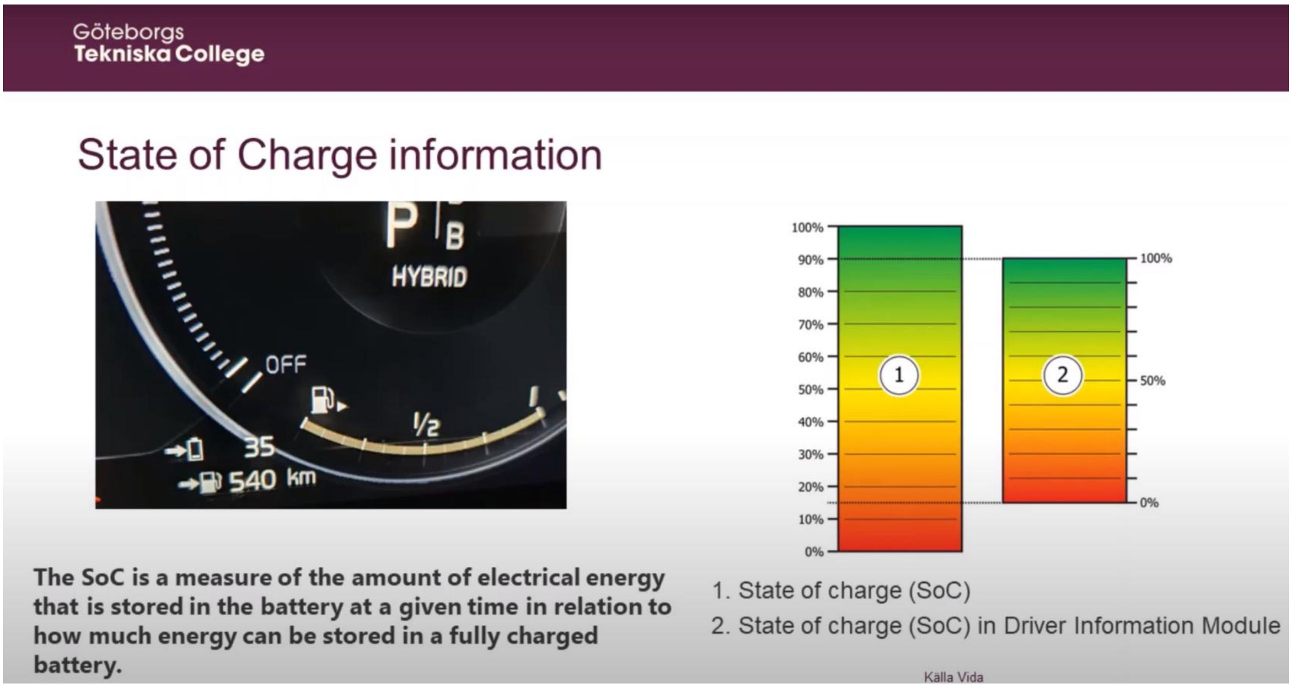
- Cell module voltage: the sum of all logical cells in the cell module.
- Cell module SoC: the average SoC of all logical cells in the cell module.
- Cell module delta voltage: the difference in voltage when comparing the cell modules with the highest and lowest value. If a cell module has just been replaced, this value is helpful for confirming that the replacement module was correctly charged/discharged to match the remaining modules in the battery. The value should generally be below 150 mV after cell module replacement.
- Cell module delta SoC: the difference in SoC when comparing the cell modules with the highest and lowest value.
- Cell module voltage, highest: the voltage of the cell module with the highest voltage. The value is used when a cell module has been replaced. The replacement cell module is delivered with a standard state of charge (SoC) of approximately 30%. The replacement cell module voltage needs to be adjusted by charging or discharging it to match the remaining cell modules in the battery, preferably to the same voltage as the cell module with the highest voltage. This is done using the cell module charger/discharger tool. The voltage value is entered in the tool using two decimals.

DESIGN FORM	
Task	***Understanding battery cell information***
Learning Objectives	Understanding real battery vs diagnostic tool. For cell status /information
Entry Level Knowledge (Theoretical)	Basic knowledge about EV battery built up. Cell, module and battery. Student must be able to troubleshoot electrical circuits with a diagnostic tool and read instructions.
Hard Skills involved	Ability to operate a diagnostic tool. Ability to use a two-pole voltage meter. Ability to identify real physical components.
Soft Skills Involved	Ability to read and understand procedures in workshop manuals and diagnostic tools.
Activities & Procedure required at EQF level (forecast)	EQF #4

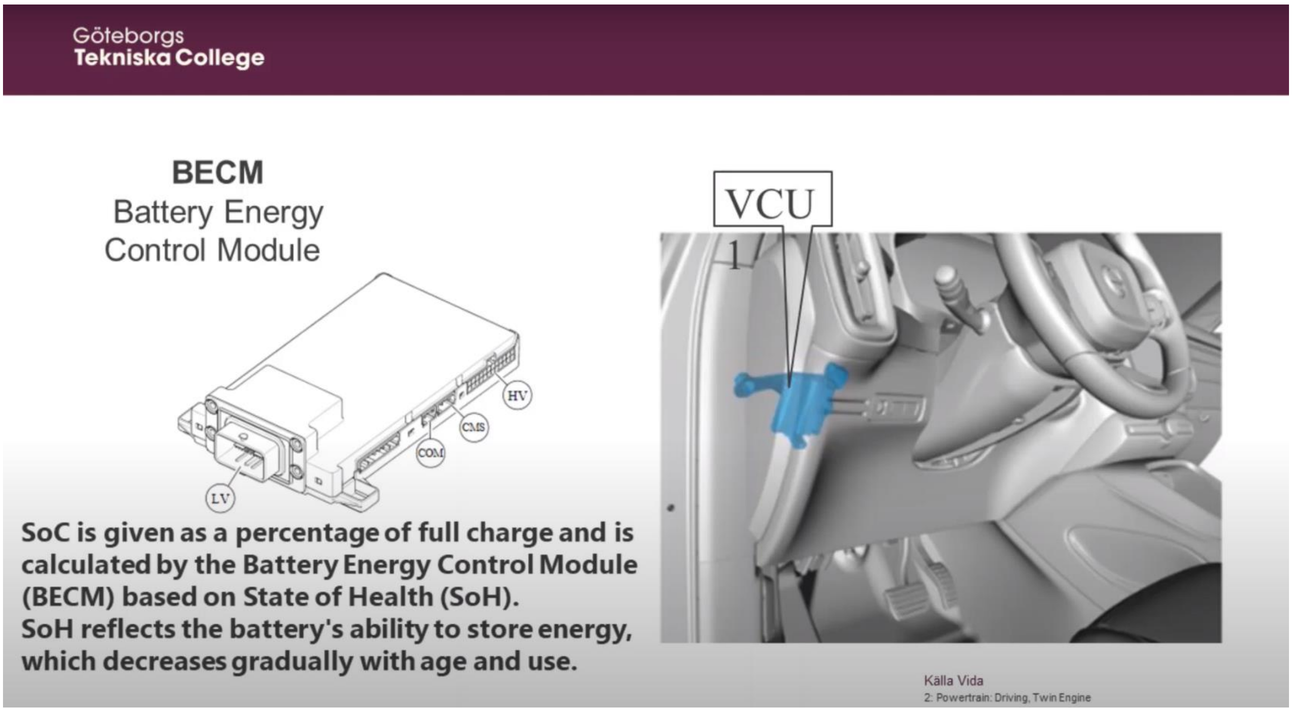
Equipment & Tools to be used	Diagnostic tool Vida
Other Professional Roles involved	EV teacher/employee
Supervision & Tutoring Activities	EV teacher/employee overview of processes during lesson, involving preparation for repair.
Expected Results / Solution	Students will have a better understanding of complete HV battery including which information that is available.

Topics

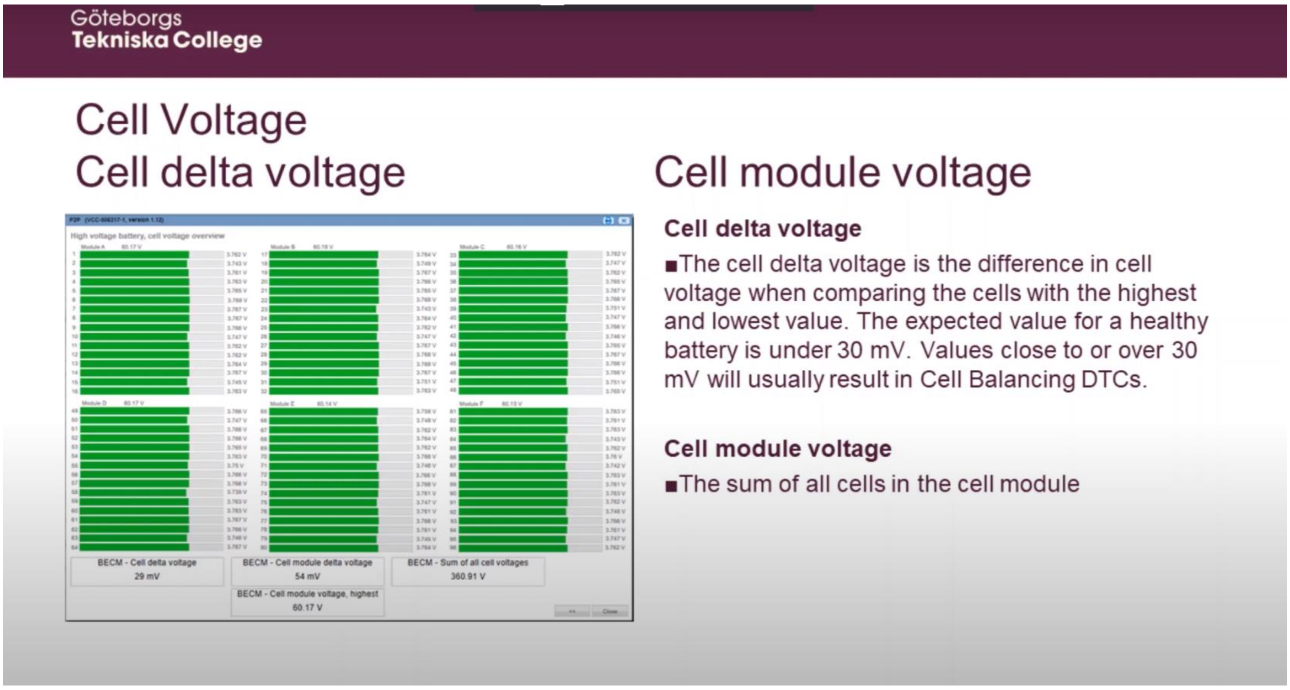
1-Understanding State of Charge information



2-Understanding how SoC is calculated through BECM

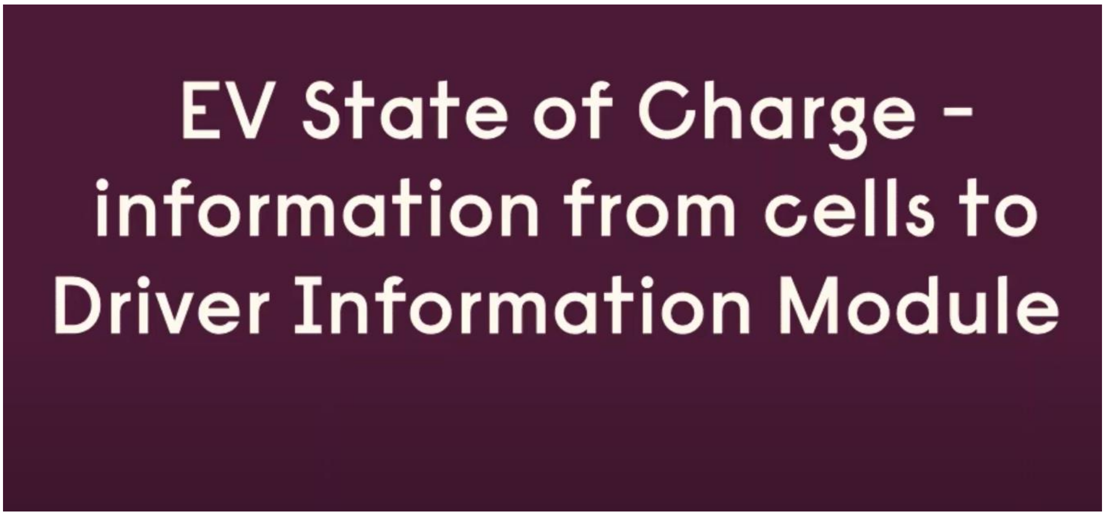


3-Understanding how cell voltage is regulated within a battery module



4- Checking on the dealer's OBD the actual State of Charge of the battery module

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:



EVALUATION FORM		
Students' Performance		
Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	YES	
Students were able to perform task	YES	

Students were able to work autonomously	In part	*Deeper knowledge on basic car mechanics and diagnostic tools to increase autonomous work*
Students were aware of safety procedures	YES	*Safety shoes only*
Students were able to use diagnostic tools	In part	*Guidance was needed to correctly interpret the interfaces of the official dealer's diagnostic tools*

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	Achieved
Entry level knowledge and skills of the students	Deeper knowledge of basic car mechanics and diagnostic tools would be needed to increase autonomous work
Equipment & Tools	Deeper knowledge of the dealers' software would be needed to operate effectively
Supervision & Tutoring	Effective

Business Technicians	
Extent of transferability of the developed skills to the job market	Partial
Suggestion for further development	Deeper knowledge of the dealers' OBD
Missing skills for students:	Knowledge of organizational / business roles
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ More corporate trainers appointed to VET teaching would be needed
Further examples of topic-related troubleshooting problems	
EQF level 3	-
EQF level 4	-
EQF level 5	-

Option 4 - Performing HV battery module replacement in Volkswagen ID.3 e-vehicle through dealer's OBD software (VAVM, Lithuania)

This program was designed and tested by the Lithuanian Team, composed by the VET provider **VAVM - Vilniaus Automechanikos ir Verslo Mokykla** and **Moller Auto Lietuva**, Volkswagen & Audi national dealer, both based in Vilnius

At VAVM - Vilniaus Automechanikos ir Verslo Mokykla there are two main specialization running on:

-Automotive Mechanic (EQF 4)

-Automotive Electric Equipment Repairer (EQF 4)

Courses do not currently provide a specialisation in HEVs/EVs or avionics circuits, yet work-based training also include maintenance and diagnostics operations on hybrid or electric vehicles. Training modules include contents, knowledge and skills suitable to become the starting point which further e-mobility training can be based upon. Such topics include the following modules:

-Engines technical maintenance

-Transmission technical maintenance

-Automobile electrical equipment repair

-Engines electrical equipment

-Transmission electrical equipment

-Automobile comfort and safety electrical equipment

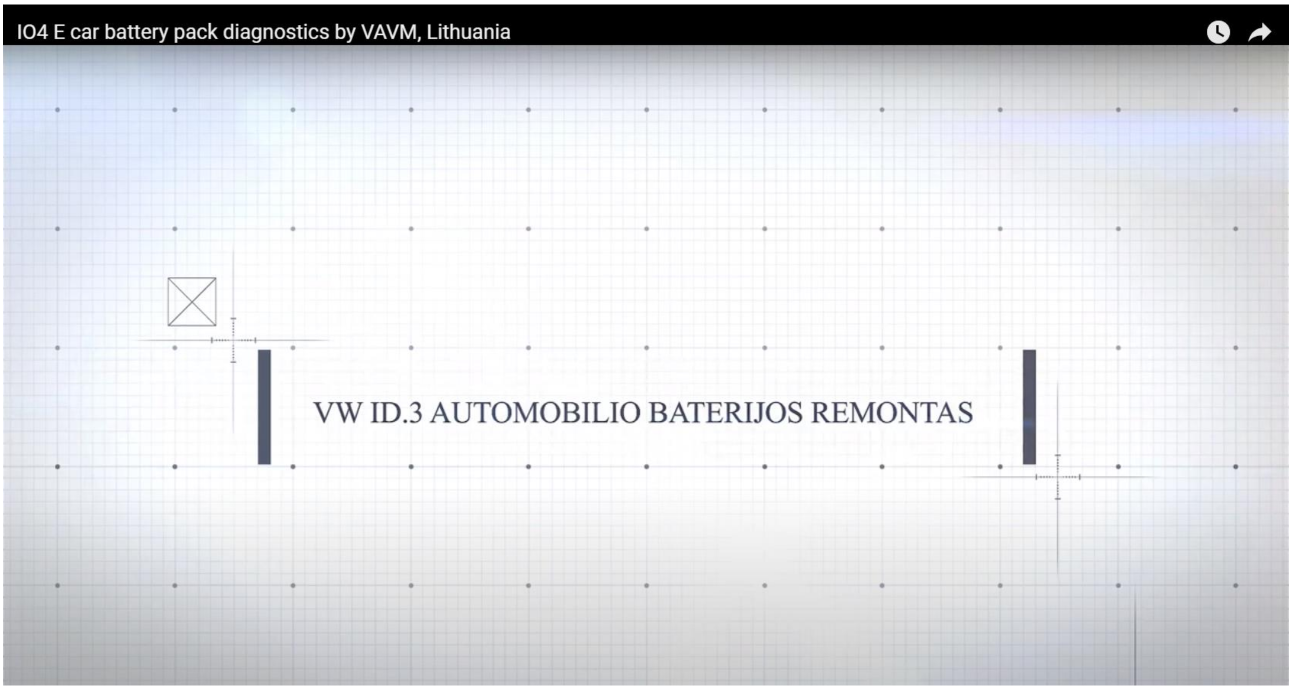
Task: performing diagnosis on an HV battery module pack through the dealer's OBD tool (onboard diagnostic tool)

Since hands-on working on HV circuits is done, only trainees who passed a certified course as EiP (electrically instructed person) are allowed to carry out such procedures.

For correct procedures about how to operate safely on an EV/HEV, please check IO2 of IG project.

DESIGN FORM	
Task	***Troubleshooting control units inside HV battery through dealer's diagnostic software***
Learning Objectives	HV battery control unit fault finding, proper dismantle, repair, coding
Entry Level Knowledge (Theoretical)	Advanced knowledge of mechanics, electronics and software interfaces
Hard Skills involved	Correct way of using mechanical and safety tools (dealer's diagnostic tester, multimeter, gloves, mechanical tools and other specific tools); Correct way of handling hazardous materials (sealant, thinner)
Soft Skills Involved	English language
Activities & Procedure required at EQF level (forecast)	III Level
Equipment & Tools to be used	Multimeter, basic disassembly tools, protective gear, wrench tool set, leak tester, dealership software, brushes. Tools to operate on HV must EN IEC 60900:2019 compliant
Other Professional Roles involved	BEV/HEV Specialist/supervisor
Supervision & Tutoring Activities	Overview of processes during lessons, including preparation & introduction to repair activities.
Expected Results / Solution	Students will know how to diagnose problem, prepare for repair, fix the e-vehicle and put everything back together correctly

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:



Procedure:

-Removing the HV battery lid with EN IEC 60900 compliant work tools, able to insulate the operator from a voltage up to 1000 Volts in alternating current or 1500 Volts in direct current.

-Identifying the dealer's OBD software for procedures related to the work scope criteria called: “Check high voltage and replace battery module(s)”.

-Checking the serial number of each battery module to identify the affected ones to replace.

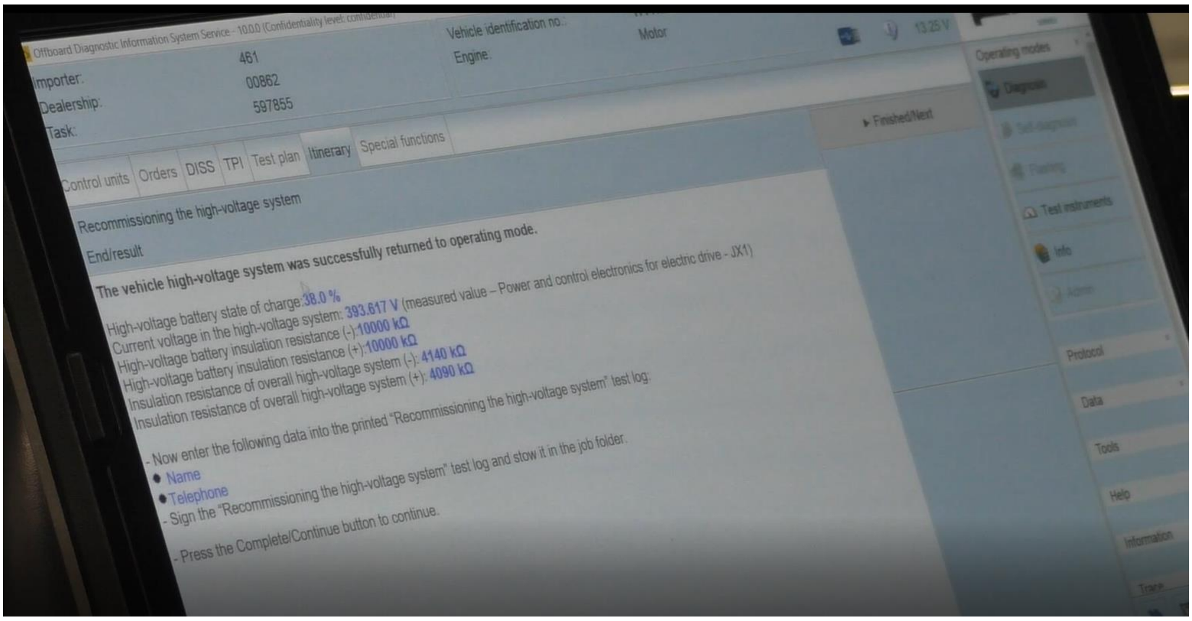
-After identifying the affected battery modules, proceed to remove them through a lift.

-Testing the voltage of the battery pack with a multimeter: when the Voltage is around 43,75 V, the determined average module Voltage is calculated dividing the total Voltage by 12, thus obtaining a mean value of 3,65 V.

-Identifying potential damage in the foam sealing the battery lid: in case any damage is detected, proceed to add new foam to ensure effective sealing.

-After completing the battery module replacement procedure, close the lid with insulating tools and pump air inside. Wait for 15 minutes and measure the pressure with a manometer to make sure no air leaks there.

Finally, the OBD software interface will give the following parameters:



EVALUATION FORM

Students' Performance

Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	YES	
Students were able to perform task	YES	
Students were able to work autonomously	In part	*Guidance from VET trainers was needed*
Students were aware of safety procedures	YES	*Electrically isntructed people only*
Students were able to use diagnostic tools	In part	*Guidance was needed to correctly interpret the interfaces of the official dealer's diagnostic tools*

VET Teachers & Trainers

Learning Outcomes	Achieved
How to make it easier	Learning the correct operating procedure by video beforehand
How to make it harder	Giving different faults to solve to different groups of students.
Expected results	Achieved
Entry level knowledge and skills of the students	The general level was adequate.
What knowledge or skills could be improved?	Introducing different dealer's software interfaces
Equipment & Tools	Students used them partly correctly. Protective gears should be used more carefully.
Supervision & Tutoring	Effective
Potential improvements	It is possible to have multiple "dummies" for HV batteries. In that way more students could learn opening/closing/checking HV battery control units
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	Expanding training facilities with different vehicle models batteries

Missing skills for students:	Ability to put work procedures in practice
Development of teachers' role:	More connections with the corporate sector
Further examples of topic-related troubleshooting problems	
EQF level 3	Charging/discharging HV system
EQF level 4	Checking HV battery leaks
EQF level 5	Checking HV battery control units inside HV battery

Option 5 – Diagnosis of a HV auxiliary battery @ ITS MAKER Academy, Italy

Such a program was run by the EQF 5 level courses within the Fondazione ITS Maker, based in Bologna, training Higher Technicians in advanced technology, mechatronics and automotive fields.

Within IG2 project implementation, there are namely two courses with e-mobility related contents:

- Higher Technician in Hybrid, Electric and Endothermic Engines (EQF 5)
- Higher Technician in Electric & Connected Car and Assisted Driving (EQF 5)

Since both profiles envisage high specialisation standards, attainable with a tertiary education course after the general upper secondary certificate (EQF 4), the current IO4 program is only targeting VET learners with prior knowledge and skills about:

- Electrical schemes of vehicle circuits
- Electrical and electronic technologies and applications
- Installation and maintenance technologies and techniques

The IO4 task run by the Fondazione ITS Maker course in hybrid, electric and endothermic engines is about diagnosis of the HV system of a Toyota Auris Hybrid vehicle.

DESIGN FORM	
Task	***Diagnosis on HV auxiliary battery of a Toyota Auris Hybrid vehicle***
Learning Objectives	Knowing the various vehicle voltage circuits and their components for correct and safe maintenance.
Entry Level Knowledge (Theoretical)	Electronics and electrical engineering, reading symbols and diagrams of vehicle electronics

Hard Skills involved	Holding a qualification as an automotive electrotechnician or autronic technician
Soft Skills Involved	Applying safety regulations, especially those with electrical hazards
Activities & Procedures required at EQF level (forecast)	Assembling wirings and electronic units accurately
Equipment & Tools to be used	Soldering station and various instruments for measuring alternating and direct electrical current
Other Professional Roles involved	Plant designers, component manufacturers and recycling technicians
Supervision & Tutoring Activities	Correct use of measuring equipment and safety devices
Expected Results / Solution	Assemblying or redesigning electrical circuit parts.

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:

Procedure:

1. Battery dismantling

First of all, the operator must be able to locate exactly where the HV battery is stored within the e-vehicle. Documentation can be found at Schede di Soccorso website, a multi-language Swiss website offering help files with the structure of the engine, battery location and other useful information about any car brand.

Italian-only similar website with safety data sheets available at Scheda di Soccorso.

After the battery is located, it is possible to remove it according to the safety procedures described in Output 2 and Output 3 of the present IG2 project by ITS Maker Academy.

2. Safety precautions and individual protection tools

Class 3 and 4 multimeter need to be used when high-voltage is involved. Air-proof class 0 insulating gloves are needed too, as well as googles and a face shield to protect the operator from any electrical arc.

3. Checking voltage on HV battery

Use a multimeter and a 12-Volt battery to test the tool beforehand. Never proceed to measure the voltage on the HV battery, because it is not sure that the measurement is correct. So, first measure voltage on a low-voltage battery, then proceed to measure it on the HV battery, and later go back to the low-voltage battery. If the third measurement is the same as the first, all the measurement are correct.

4. Control of high-voltage battery relays

First, connect and check the positive relay, and then the negative relay. Voltage has to be 0 V.

Co-funded by the Erasmus+ Programme of the European Union

EVALUATION FORM

Students' Performance

Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	In part	
Students were able to perform task	YES	
Students were able to work autonomously	In part	*Guidance was needed from the trainer*
Students were able to find faults	In part	*Guidance was needed from the trainer*
Students were aware of safety procedures	YES	
Students were able to use diagnostic tools	In part	*Guidance was needed to correctly interpret the interfaces of the official dealer's diagnostic tools*

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	In part: it takes more practice to gain experience
Entry level knowledge and skills of the students	Partly adequate. Learners are still lacking practical skills
Equipment & Tools	Deeper knowledge of the dealers' software would be needed to operate effectively
Supervision & Tutoring	Effective
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	-
Missing skills for students:	Ability to apply work procedures in the learning environment
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ More corporate trainers appointed to VET teaching would be needed

Further examples of topic-related troubleshooting problems	
EQF level 3	Theoretical knowledge of systems and knowledge of the main systems according to the levels
EQF level 4	Bing able to perform system calibrations and to replace defective or damaged components
EQF level 5	Being able to code the main ECU and carry out an adjustment and calibration of the systems

3. Collecting VET learners' feedback

As stated in the IO1 paper about designing a pilot Train-the-Trainers program about e-mobility, a relevant part of the program itself relies into collecting the learners' feedback about both their appreciation and their self-evaluation about the training experience.

Questions might vary according to the learning objectives of the experimentation and the EQF level of the VET provider, but on a general rule the following criteria should be met in order to administer feedback questionnaires to measure the impact of the training activities:

-forms should be collected anonymously to make sure respondents are free to express their sincere and honest feedback about the training program, either on a paper or digital format;

-questions might be multiple-choice or on a scale, but in any case some room for further comments or remarks should be left;

-the extent to which the training workplace helped students develop e-mobility skills should be assessed;

-the effectiveness of the mentoring or supervisory activities should be assessed;

-the extent to which prior knowledge and skills were allowed learners to make the most out of the training program should be assessed;

-the perception, on the learners' side, of actual development of e-mobility skills should be assessed;

-the extent to which learners think to be suitably prepared to transition to the job market.

Examples of the collected feedback can be seen from the charts below, which report genderless aggregate data from all the countries and EQF levels involved.

Answers with scale from 1 to 5 mean that respondents were asked to rate the sentence in the questions with a score from 1 (absolutely not) to 5 (absolutely yes).

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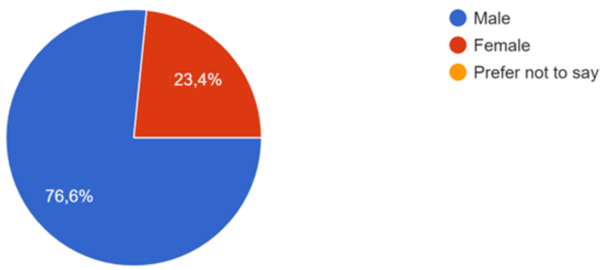
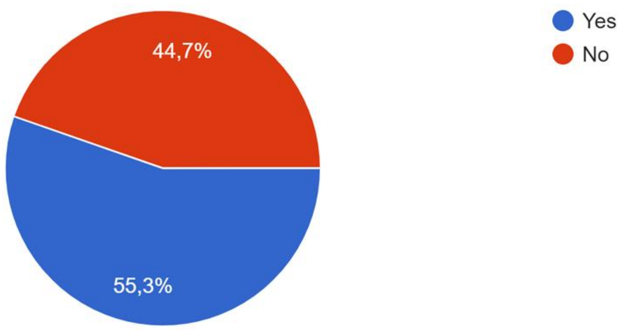
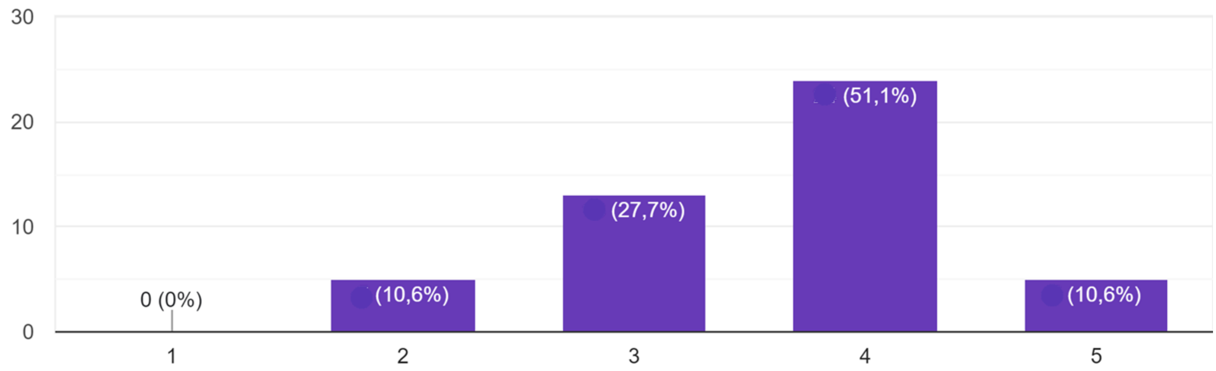
Your gender



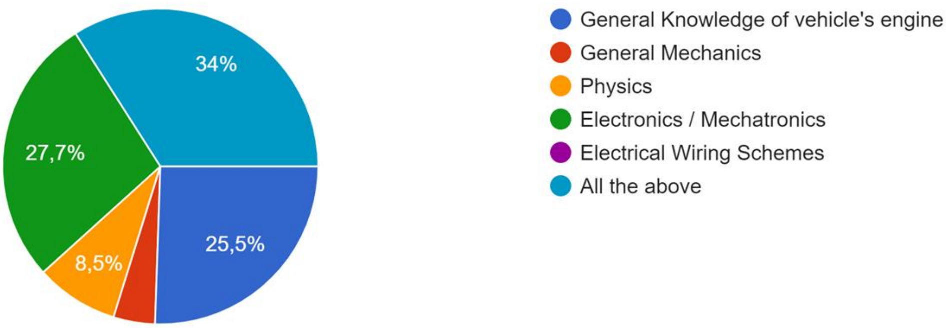
I already took classes in electro-mobility or HEV/BEV before participating in the project



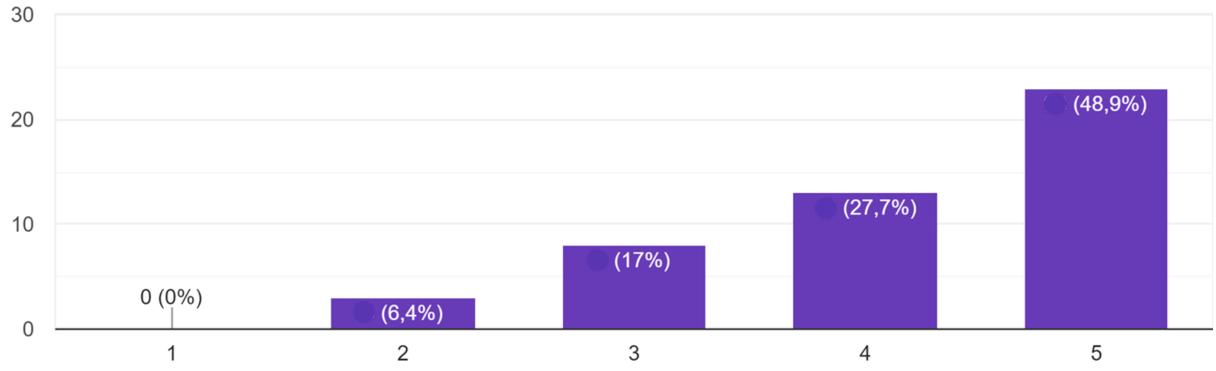
I think my previous knowledge & skills level was enough for me to take part in HEV/BEV testing



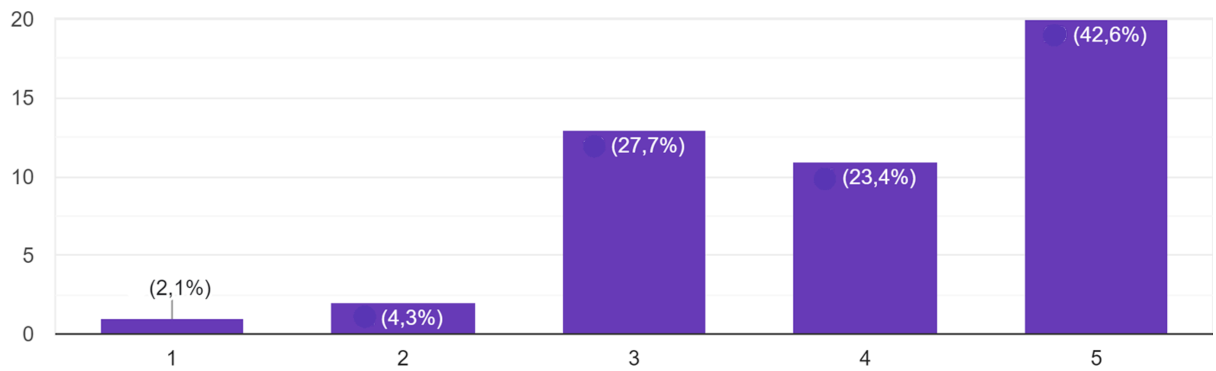
Which of the following was most helpful for you to make the most out of the HEV/BEV testing?



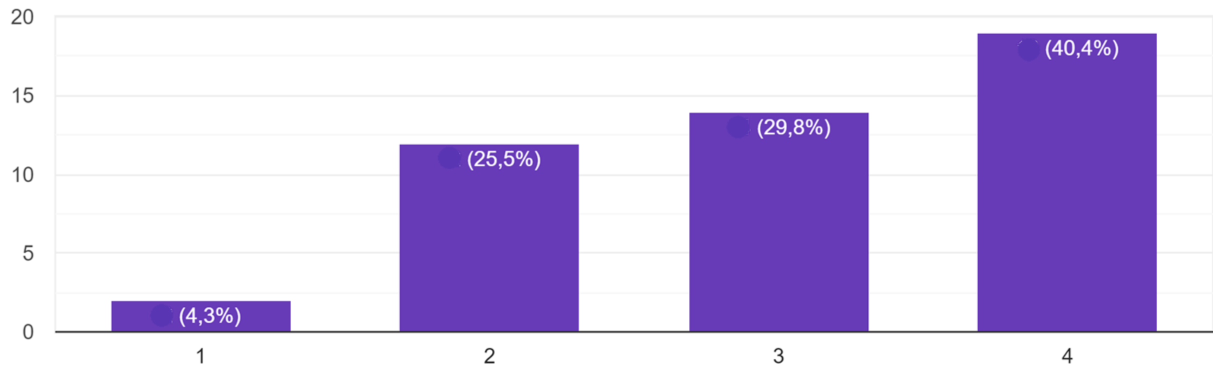
After the testing, I think I developed knowledge and skills about how a to work safely on an HEV/BEV vehicle



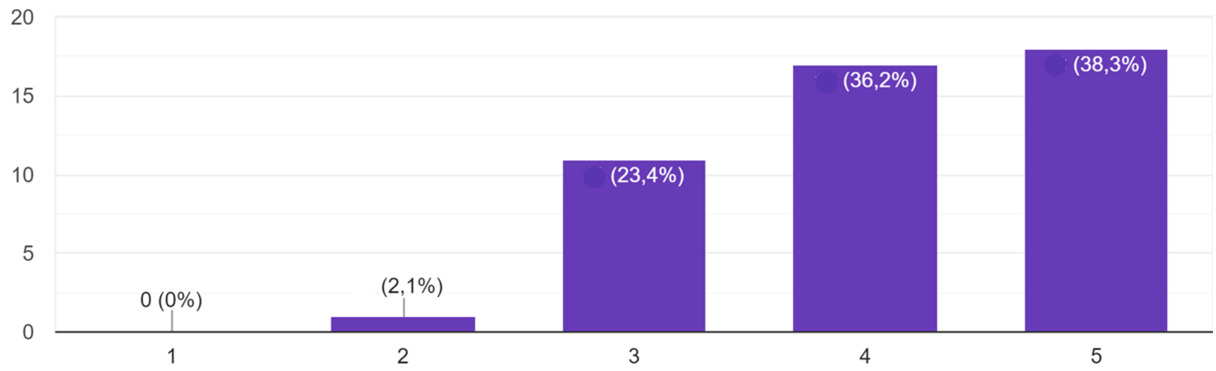
I think I can read electrical circuit wiring schemes



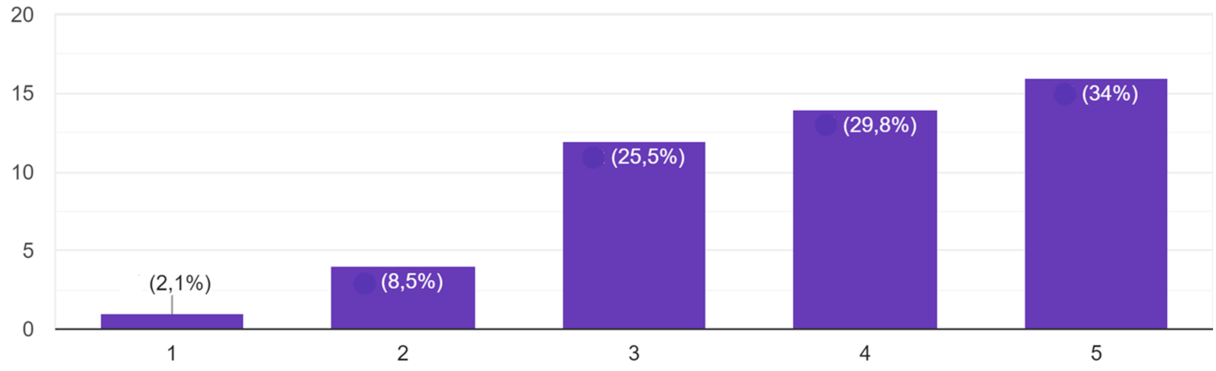
I developed knowledge and skills about ECU - Engine Control Units circuits damage & repair



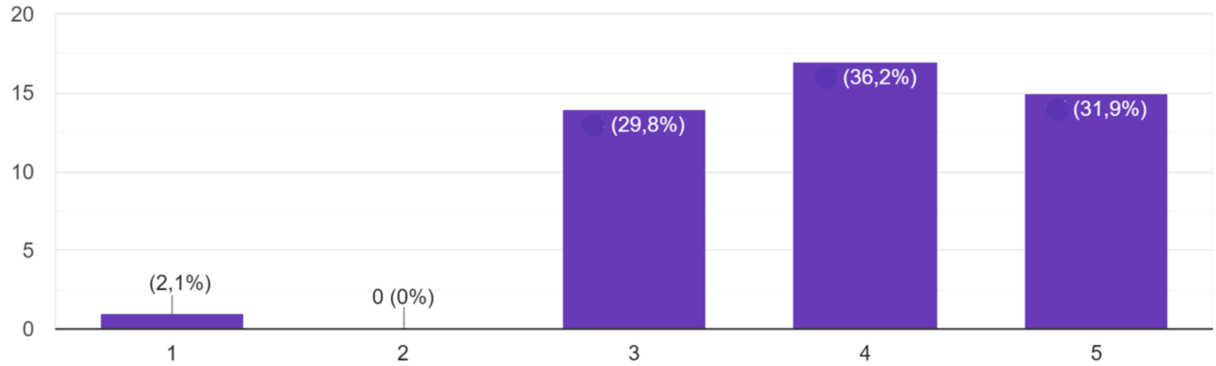
I developed knowledge and skills about ADAS calibration and diagnostics



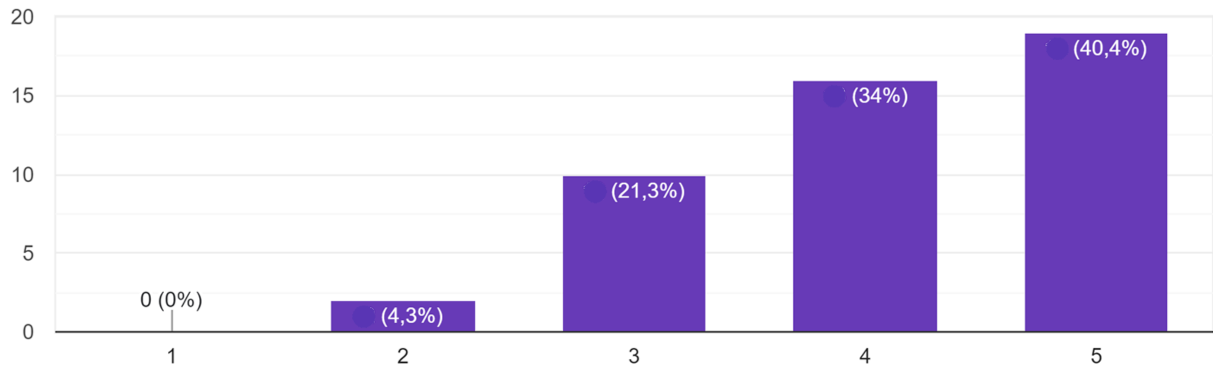
I developed knowledge and skills about how to perform failure diagnosis & repair in a EV/HEV system



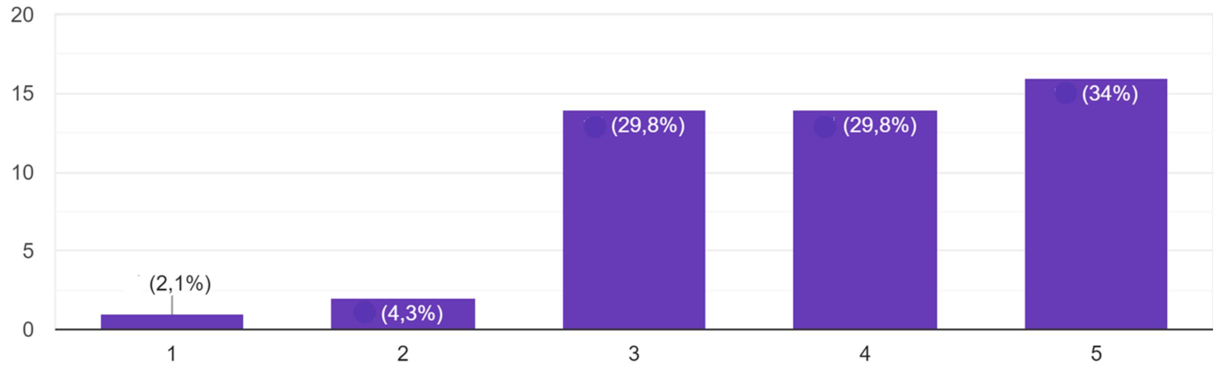
I developed knowledge and skills about assisted braking systems in a EV/HEV system



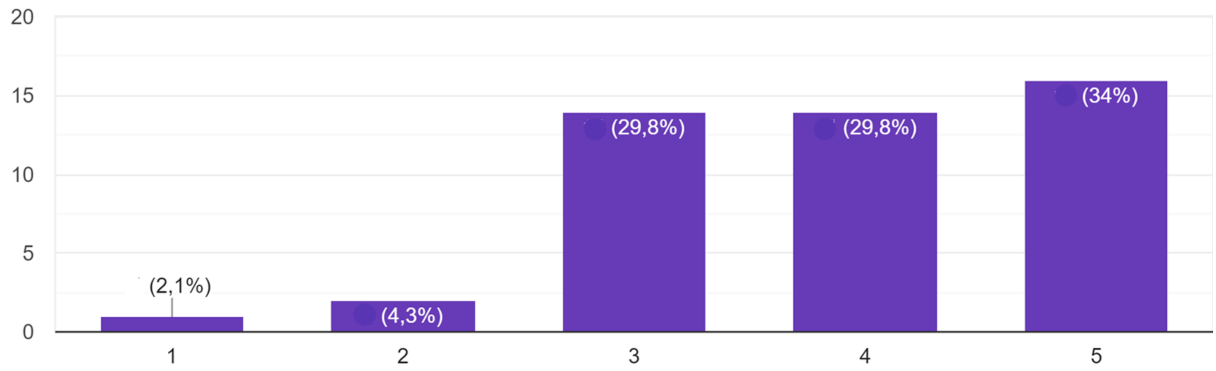
I developed knowledge and skills about EV/HEV battery

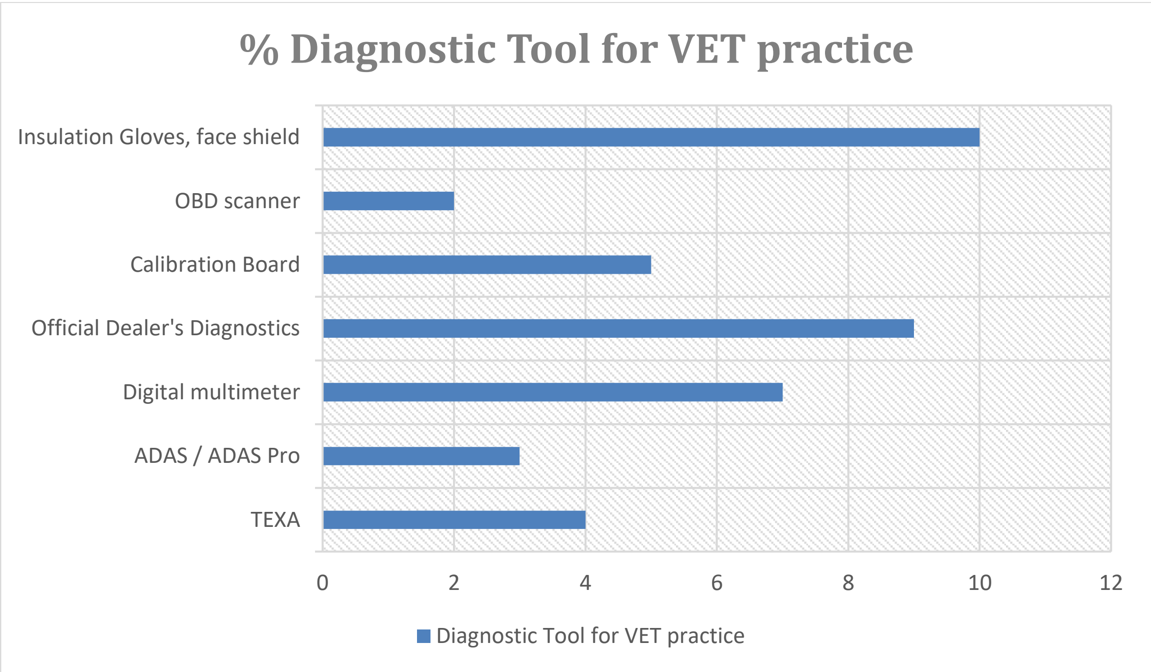


I developed skills in using EV/HEV diagnostic tools

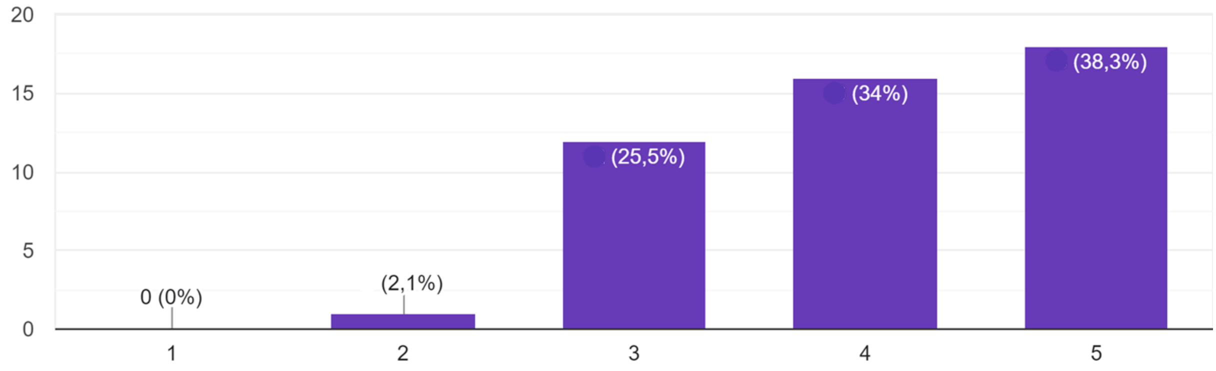


I developed skills in using EV/HEV diagnostic tools

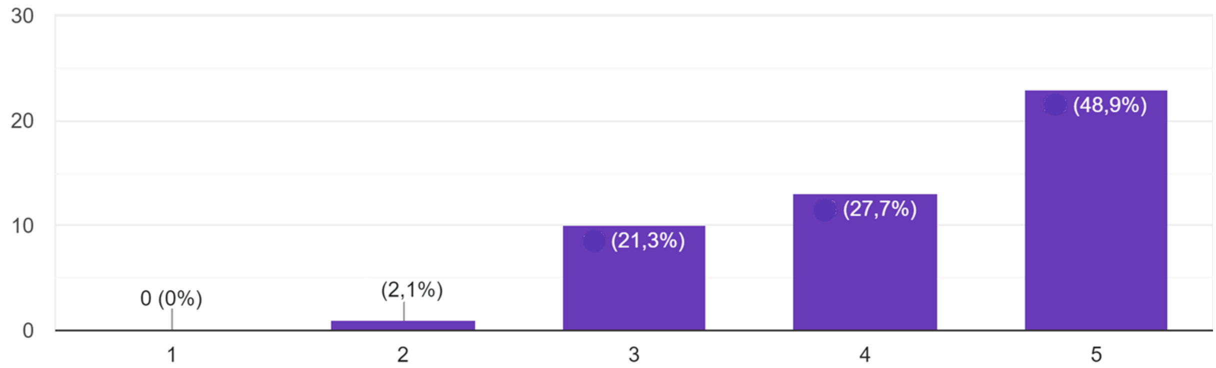




I think I have better ideas about how a company workplace or a production plant or car workshops works



Thanks to the testing, I think I am better prepared for the automotive job market



Conclusion: who is this paper for?

This paper represents the outcome of Intellectual Output 4 of “Innovation Garage of Garages” Erasmus+ project, aiming at developing green skills for the automotive sector at VET level.

The specific goal of such a paper is to provide guidelines for VET teachers and trainers willing to introduce hybrid or electric engines, high voltage and their components as a modular or integrated path within mechanics or automotive courses.

Multiple actors co-designing the training contents, the workplace layout and tools, as well as the organisational details of the didactic methodology (roles of trainers, facilitators, evaluation and assessment criteria, is the special footprint of the project. Since “Innovation Garage” is a worldwide methodology to introduce bottom-up multi-stakeholders innovation over the workplace premises, what this project is aiming at is renovating the way which “workshops” or “garage” training is usually performed.

So, this is just a proposal that needs to be customised with specific contents according to the target learners and the regular training courses within a VET organisation.

IO4 paper is suitable both for teachers and trainers at I-VET level (schools, training centres for young people or adults) from EQF levels 3-4, or even for H-VET at EQF 5 level (tertiary education other than university level). Nonetheless, e-mobility training can involve managers, technicians or trainers at company level - either at production houses, or repair workshops, or dealers, whenever workers need to develop or upgrade their skills about the management and maintenance of HV batteries, of HEV/EV vehicles and their components.

Co-funded by the Erasmus+ Programme of the European Union

Project no. 2020-1-IT01-KA202-008555

“Innovation Garage of Garages”

IO5 – Intellectual Output 5

Training programme covering the updating, maintenance and repair of on-board avionics, based on the work-based learning methodology located inside the innovation garage

Output Type: Open / online / digital education

OER – Open Educational Resource

The project is funded by ERASMUS+ Programme of the European Union. The content of this material does not reflect the official opinion of the European Union, the European Commission and National Agencies. Responsibility for the information and views expressed in this material lies entirely with the author(s). Project number: 2020-1-IT01-KA202-008555

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Training Program on avionics circuits maintenance on EV/HEV

Language: English

Author:

Innovation Garage of Garages Partnership

Coordinator: Cisita Parma scarl, Italy

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Intro: the learning model

Since VET providers maintain close cooperation with the industrial sectors, especially within the automotive field, workplace training is the most valuable asset that educational institutions hold to develop job-related skills, facilitating the learners' transition into the labour market.

In this view, the "Innovation Garage of Garages" project (named "IG2" below), holds the purpose to bring VET providers and automotive companies together (either construction houses, OEMs manufacturers, dealers, car-repair workshops) to co-design training paths & learning environments suitable for the development of green mobility skills, in terms of:

a-learning goals & contents;

b-layout of the training workplace;

c-tools, machinery and equipment.

According to the panorama of the green skills and job profiles within the Automotive sector, identified in the IO1 paper, the main 5 work processes that IG2 project deals with are:

IO2: Installation & Assembly of EV/HEV engines

IO3: Maintenance of EV/HEV engines

IO4: Configuration & calibration of Avionics systems in e-vehicles

IO5: Maintenance of Avionics systems in e-vehicles

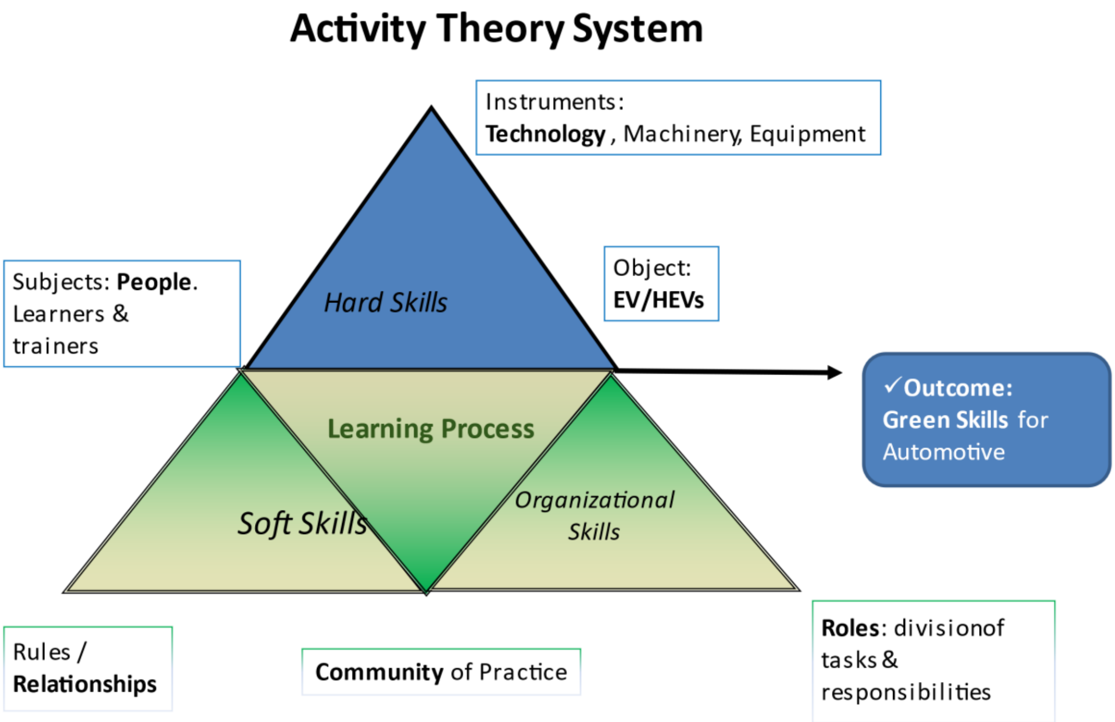
IO6: After-sales assistance & safety issues related to EVs/HEVs

The training environment should make practical learning accessible and inclusive, and students should learn from work processes and organizational structure, as well as use technological assets that are the closest possible to the real workplace layout.

This is what IG2 partnership agreed to call "situated learning", identifying the dynamics of a training environment equipped with technological tools, where learners are immersed into a productive process governed by supervisors performing a mentoring and leading role, aimed at manufacturing a given product.

The learning model inspiring the project methodology is the "Activity Theory" framework by Yrjö Engeström (1987/2015), representing the third generation of academic researchers studying the topic, after the contributions of cultural-historical psychology from the Russian Vygotsky to Leontyev.[1]

[1] For a very introductory documentation over the "Activity Theory" system please see:
- Andy Blunden "Engeström Activity Theory and Social System", 2015



According to such model, the overall learning process is composed of two main dimensions: the immersive experience of actually doing some activity or of producing a real product within a given environment, such as the school lab or the training facility, or workplace itself. This is the dimension where the e-mobility hard skills are being developed, thanks to the interaction of 3 main elements: people (learners & trainers) as *subject* of the process; tools (such as technology, equipment and machinery) as *instruments* making the learning process come true; the *electric/hybrid vehicle* or one or more of its components, as the *object* of the learning process itself. The outcome of the interaction of such 3 elements is the expected learning goal itself for the relevant testing, or, more generally, the green skills for the automotive sector.

Underneath the upper triangle, the Activity Theory puts the hidden or intangible part of the learning process, which is related to the development of all the soft skills implied by interacting within a complex organisation of people. This is what happens to workers in a company, but workplace learning or workplace simulation actually reflects the very same dynamics. As a matter of fact, within an automotive production site or within a car repair workshop, for example, workers are assigned different roles, responsibilities and tasks which actually shape the interpersonal relationship happening over there. VET learners, either in their initial training at school, or involved in lifelong and continuous training at work, are immersed in a community of

- Oliver Ding, [Yrjö Engeström: the Activity System Model](), 2021

practice, where knowledge, skills & behaviours are shared, promoted, rewarded or even confuted or rejected.

IG2 project, by bringing together VET providers and companies, aims at co-designing learning experiences for the development of e-mobility skills, keeping in mind such behavioral and organizational learning model.

1. Referencing Output 5 e-mobility skills to the current job qualification frameworks

Output 5 of the IG2 project is focused on the development of skills related to the **maintenance, repair and diagnostics** of **electronic circuits (**including **high voltage batteries)** and **avionics circuits**, such as **assisted** or **autonomous drive** systems and of relevant **sub-components, into electric or hybrid vehicles.**

According to IG2 partners, such tasks can range from simple and basic ones, attainable from EQF 3 operators or even lower, e.g. C-VET operators achieving EQF2 vocational qualifications, to technical or supervisory roles (EQF 4 - EQF 5).

Output 5, outlining the train-the-trainers program for VET teachers willing to introduce e-mobility in their didactic courses, collects the job qualifications in the automotive sector according to the ESCO framework and from the job-profiles and skills card classified by the Erasmus+ Sector Skills Alliances DRIVES 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B (for the general automotive sector) & ALBATTS 612675-EPP-1-2019-1-SE-EPPKA2-SSA-B (specifically for the battery sector).

According to such classifications, Output 5 refers to the following job roles matching the EV/HEV engine assembly operations:

	DRIVES Development and Research on Innovative Vocational Education Skills	albatts
Automotive Battery Technician		Battery Manufacturing Technician
Battery Assembler		Battery Module Assembly Technician
Battery Test Technician		Battery Quality Technician
		Battery Recycling Technician
Avionics Technician	ADAS /ADF Testing & Validation Engineer	
	Sensor Fusion Expert	

	Connected Vehicles Technician	
	Automotive Cybersecurity Tester	
	Highly Automated Drive Engineer	
Electronic Equipment Assembler	Automotive Mechatronics Expert	
Electronic Equipment Inspector		
Vehicle Electronics Assembler	Robotic Technician	
	Predictive Maintenance Technician	
Microelectronics Engineering Technician	Functional Safety [Engineer/Technician]	

Among all the e-mobility related job qualifications that ESCO, DRIVES and ALBATTS put together, the one listed above are the ones that are at least partly relatable to the training programs that were designed and tested by the IG2 VET providers' consortium, and that will be described in the chapters below.

2. Designing, testing and evaluating results of training programs about the maintenance - diagnostics of electronic or avionics circuits in EV/HEV

During the Pilot Phase of IG2 project (Output 1), partners agreed that the basic structure of any topic-specific program about e-mobility should start with a joint business-VET design phase, including:

– identifying learning objectives,

– setting knowledge or skills entry requisites for VET learners,

– identifying the work procedures to implement,

– setting the training workplace layout and necessary tools/equipment,

– deciding on the expected outcomes of the troubleshooting,

– establishing supervisory and tutoring roles

VET providers were not assigned prescriptive rules about which relevant topic should be chosen for a training program about EV/HEV engine assembly or installation. Multiple reasons usually affect the choice of the specific topic to focus on, and the following criteria should be taken into consideration while evaluating the potential options:

a) whether or not the VET provider is already including specific training modules or contents about EVs/HEVs in the institutional offer;

b) the EQF level of the training course where e-mobility should be taught or introduced for the first time;

c) the general level of technical knowledge & skills of the target learners as well as their behavioural / communication skills and/or their potential fewer opportunities profile

With regards to point a), this is absolutely the most significant and diriment criterion that should guide the choice of VET trainers: are learners already trained about safety precautions around HV batteries and electric or hybrid engines? Are learners already able to read the electrical schemes of the car? Are they already familiar with the structure and components of internal combustion engines whatsoever?

If this is case, it is probably a good choice to delve into EV/HEV engines specific topics such as electrical insulation or HV battery modules checks, or calibration of ADAS systems, on-board cameras and radars. On the opposite side, learners who are not trained about electrical risks must never work hands-on with HV batteries. This happens with upper secondary education courses at EQF 3 or EQF 4 levels, where students work just on the mechanical part of engines. In this case, in the first place mandatory electrical safety courses must be attended from students, and demo classes about HV batteries where trainers show the correct

battery management procedures without students being involved, or using electronical panels simulating the engine mechanism or the switches of sensors regulating the circuits of the car, are good examples of introductory activities.

Furthermore, VET trainers should take into consideration the general profile of the target learners involved:

-EQF level of the training course and previous knowledge & skills gained by students

-the age of the learners: is it young people in initial learning or is it workers engaged in an upskilling or re-skilling course within C-VET training paths?

-the general lifelong background of the students involved: is there any type of potential disadvantage represented in the learning group?

This might range from physical or cognitive disabilities, to migrant background or language barriers preventing students from a full exploitation of the learning opportunities, or even age barriers, in the case of underqualified over-50 workers in need of a skill upscale to prevent job loss. In any of such cases, special arrangements should be envisaged by trainers in order to choose the most inclusive and barrier-free training environment possible. In case any learner has a physical disability, the workplace should be designed in a way that the learner is safe throughout the testing, yet he or she can either see the work procedures or operate some of them according to both the work safety procedures and to what the medical conditions allow. In case the learner has a mild cognitive disability, VET trainers should design the experimentation assigning tasks to small students' teams with an appointed leader with a distributed share of duties, so that everybody can be involved in the experimentation with different level of difficulty or responsibilities.

Team work and practical learning is especially recommended and effective in case of migrant learners with little command of the local language, as graphic or synthetic work procedures help understand topics or tasks quicker than a theoretical frontal class.

Evaluation. As a part of O1 train-the-trainer program results, IG2 project partners established a protocol for the evaluation of the work-based testing, to assess to which extent the program itself was successful for VET learners to develop e-mobility skills. Such assessment is a simple form with questions addressed both to VET teachers or trainers, and to business technicians, since the workplace training should be co-designed on both parts.

Teachers or trainers should assess:

– whether or not the learning goals have been met,

– whether or not the work-based testing delivered the expected outcomes,

– to which extent the expected knowledge and skills have been gained by the students or not,

– whether or not the diagnostic tools were used properly,

– whether or not the supervisory and tutoring activities were adequate to provide learners with the guidance they needed.

When relevant, teachers might also provide additional information about the main difficulties overcome, which tasks were missing or not correctly performed during the experimentation, as well as suggestions on how potentially making the experimentation easier or harder according to the learners' profiles.

On the other hand, business technicians should assess to which extent the knowledge and skills that students developed thanks to such a training experience are indeed useful and transferable to the job market. Furthermore, business technicians might as well provide further examples of troubleshooting and diagnostics experimentations on similar topics, that they believe might help learners develop missing skills about working on EVs/HEVs at different EQF levels.

Let's see examples of the training programs that each country team participating in IG2 project designed & tested.

Option 1 –ADAS maintenance & application problems at IIS A. Ferrari, Maranello, Italy (EQF 3-4 levels)

Such tasks were performed by students attending the technical and vocational courses (EQF 4) at IIS "A. Ferrari" in Maranello (Modena, Italy).

Based on the learning objectives of the project - getting students familiar with the electric and hybrid vehicles, batteries and engines, the following study courses were identified as most suitable to run IG2 project's experimentation:

- Maintenance and Technical Assistance (EQF 4)
- Technician for the Construction of Transportation Means - Road Vehicles (EQF 4)

At such a level students attend mandatory work safety courses - both general safety recommendation at work and specific mechanic and electrical risk training, but, given their young age, they are not usually trained as EiP (electrically instructed person) and they cannot work with high voltage batteries or circuits.

Nonetheless, it is possible to introduce theoretical knowledge about what ADAS is, its main functions and technology and the relevant European and national legislations. At this level, it might be also possible to have students work at the calibration of real electronic systems like ADAS, provided that no electrical voltage is on.

ADAS is an acronym standing for Advanced Driver Assistance System, envisaging 6 different levels of automation, ranging from no assistance whatsoever to complete autonomous drive – not currently legal in Europe.

According to the definition of the European Union[2], ADAS in known as a "*vehicle-based intelligent safety system which could improve road safety in terms of crash avoidance, crash severity mitigation and protection, and automatic post-crash notification of collision; or indeed as integrated in-vehicle or infrastructure-based systems which contribute to some or all of these crash phases. More generally, some driver support systems are intended to improve safety whereas others are convenience functions*".

In Output 4 students studied what ADAS system are and how they can assist the driver from potential risks while travelling, such as hitting obstacles on the road, sudden sickness or sleepiness. In all such situations, ADAS systems offer extra help and assistance to the driver, through emergency braking systems, the lane assist and lane camera functions, preventing fatal crashes and injuries.

In Output 5 students focused on a double perspective:

-problem of applicability of ADAS systems and legislative rules in Italy and in Europe. Despite technology allows complete autonomous drive systems, autonomous vehicles are not entirely legal in Europe. From July 2022 the Vienna Convention establishes that ADAS systems terminate the experimentation phase and enter the application phase. Nonetheless, each country within the EU must deliberate on the national reception of the communitarian law: for this reason, only level 2 autonomous drive systems are allowed in Italy. On the other hand, from 2022 a few ADAS systems are compulsory on newly-manufactured cars in Europe, such as adaptive cruise control, emergency brake, lane assist, tyre pressure detector, driver's health monitoring systems, crash recording systems.

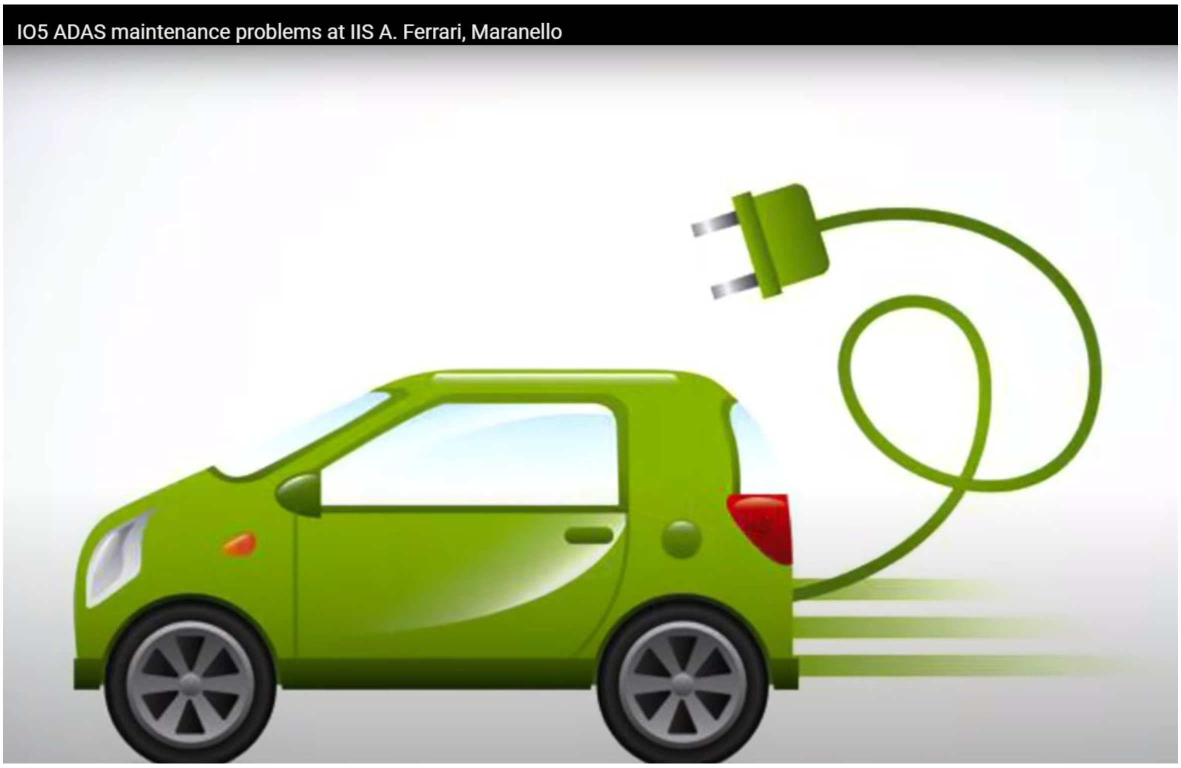
-periodical maintenance and recalibration of ADAS components. Sensors, radars and cameras that serve to receive and process data from the outside for ADAS are set to precise distance, height and position values already at the factory, i.e. when the car leaves the production lines. When replacing a body element or ADAS, it is always necessary to recalibrate the device. This serves to restore the accuracy of the systems, so that a new starting point can be defined that is useful for data processing by the control unit.

DESIGN FORM	
Task	***Recalibration, maintenance and replacement of ADAS systems in vehicles***
Learning Objectives	Getting to know when ADAS systems may help drivers managing the vehicle in emergency situation on the road

[2] European Commission's "Advanced Driver Assisted Systems" 2018 by ERSO, European Road Safety Observatory.

Entry Level Knowledge (Theoretical)	Able to recognize electronics/avionics components (ADAS systems)
Hard Skills involved	Able to operate with an OBD (Onboard diagnostic tool)
Soft Skills Involved	Able to read and understand procedures in workshop manuals and diagnostic tools. English language
Activities & Procedure required at EQF level (forecast)	III Level
Equipment & Tools to be used	OBD dealership software.
Other Professional Roles involved	VET trainer or workshop manager
Supervision & Tutoring Activities	Theoretical explanation of avionics systems
Expected Results / Solution	Students will know how to identify ADAS components and to understand how ADAS systems take control of the vehicle in an emergency situation

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:



Educational and training materials about the EU legislation regulating ADAS systems and its functionalities are stored as open didactic materials on IG2 Google Drive Folder (Italian language only).

EVALUATION FORM		
Students' performance		
Students were engaged and interested	YES	Students were assigned the task of researching the matter and illustrating it to teachers and fellow peers, thus resulting in more individual responsibility and commitment
Students were able to apply theoretical knowledge to practical tasks	NA	Theoretical training only

Students were able to perform tasks	NA	Theoretical training only
Students were able to work autonomously	In part	With some guidance from the teachers about the ADAS topics to research
Students were able to find faults	NA	Theoretical training only
Students were able to identify safety procedures	YES	Students understood the safety rules and law regulations about ADAS systems
Students were able to use diagnostic tool	In part	With some guidance from the teachers about the dealers' OBD tools (onboard diagnostic tools)

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	Achieved
Entry level knowledge and skills of the students	Adequate level of self study
Equipment & Tools	Adequate level of awareness

Supervision & Tutoring	Effective
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	Practice on finding faults in ADAS systems
Missing skills for students:	Knowledge of organizational / business roles
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ Deeper or up-to-date knowledge of software or diagnostic tools
Further examples of topic-related troubleshooting problems	
EQF level 3	-
EQF level 4	-
EQF level 5	-

Option 2 –ADAS systems fault finding in a VW vehicle at ROC Midden Nederland

The training program was designed & tested by ROC Midden Nederland (VET provider) and Innovam (company), and is targeting VET students attending the following courses:

- First Car Technician (EQF 3)
- First Truck Technician (EQF 3)
- Technical Specialist Car Technology (EQF 4)
- Technical Specialist Truck Technology (EQF 4)

All of them already include, in the regular training paths, teaching contents about the following units:

- Hybrid and electrical drivetrain
- Electric engines
- NEN9140 (EU regulation about electrical works)
- Charging Systems
- Inverter/Converter Battery Management

Despite no high-voltage battery is involved in the calibration of ADAS systems such as radars, front camera and lane camera (see IO4), recalibration, maintenance and repair of such components do involve hands-on work on electrical circuit. For this reason, only learners holding certified electrical training certificate should be allowed to perform such operations. For further details about electrical safety when dealing with e-vehicles, ROC Midden Nederland and Innovam do include such topics in a short one-day modular course for students and workers called “Safe working on e-vehicles basics” (see Output 1), as well as in de-energization of HV battery described in Output 2 and Output 3 of the IG2 project.

DESIGN FORM	
Task	**ADAS fault finding**
Learning Objectives	Getting to know how to diagnose ADAS systems. Being able to repair or reset ADAS systems or components. Being able to perform ADAS calibration after repair (if needed).

Entry Level Knowledge (Theoretical)	EQF level 3 Being able to recognize ADAS components Knowledge about how ADAS systems and components work Knowledge of diagnosis procedures Understanding electrical wiring diagrams
Hard Skills involved	Being able to operate a diagnostic tool Being able to follow diagnosis procedures Being able to measure with multimeter Being able to use ADAS calibration equipment
Soft Skills Involved	Being able to read and understand procedures in workshop manuals and diagnostic tools Being able to read wiring diagrams Being able to work precise and accurate
Activities & Procedure required at EQF level (forecast)	Reading DTCs (diagnostic trouble codes) and follow fault finding procedures Electric Measurements of suspected wiring and components Setting-up ADAS calibration equipment (if needed)
Equipment & Tools to be used	Diagnostic tool Multimeter ADAS calibration tool
Other Professional Roles involved	Workshop manager who is responsible for safety. He has to check if repair and calibration is done correctly.
Supervision & Tutoring Activities	Theoretical explanation of ADAS systems and diagnosis procedures; Guiding students during execution of the calibration
Expected Results / Solution	ADAS diagnosis and repair is performed correctly, if needed ADAS calibration is performed and vehicle is safe to drive in.

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:

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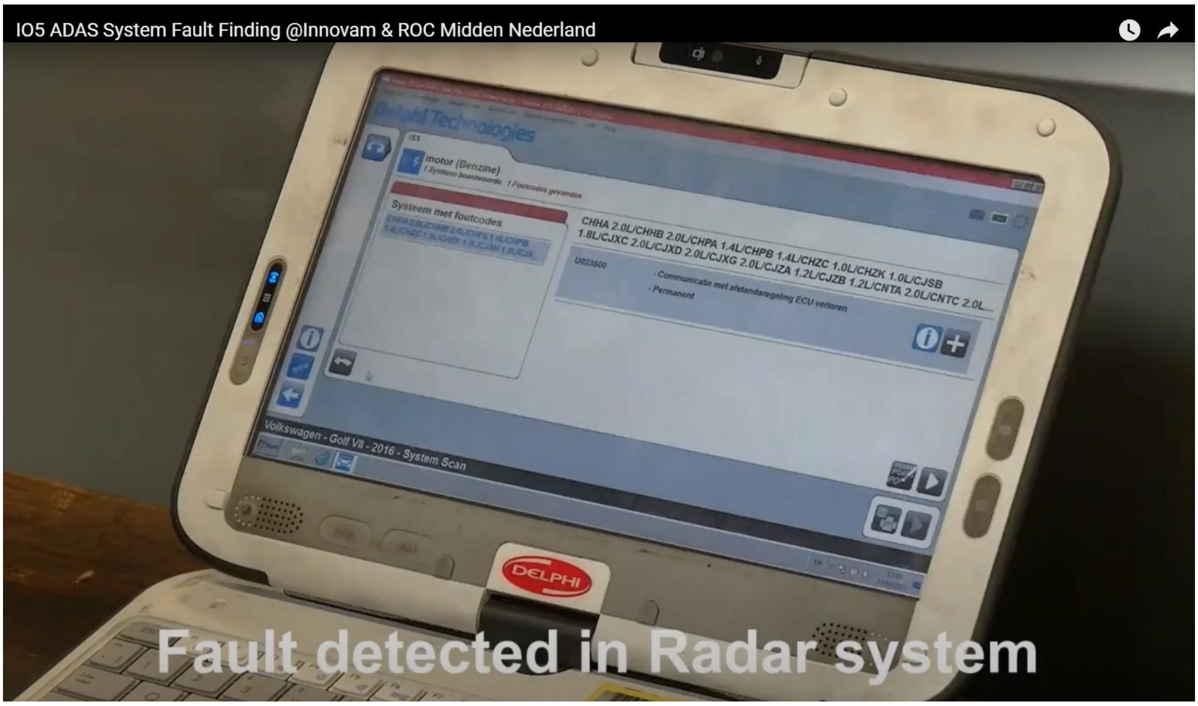
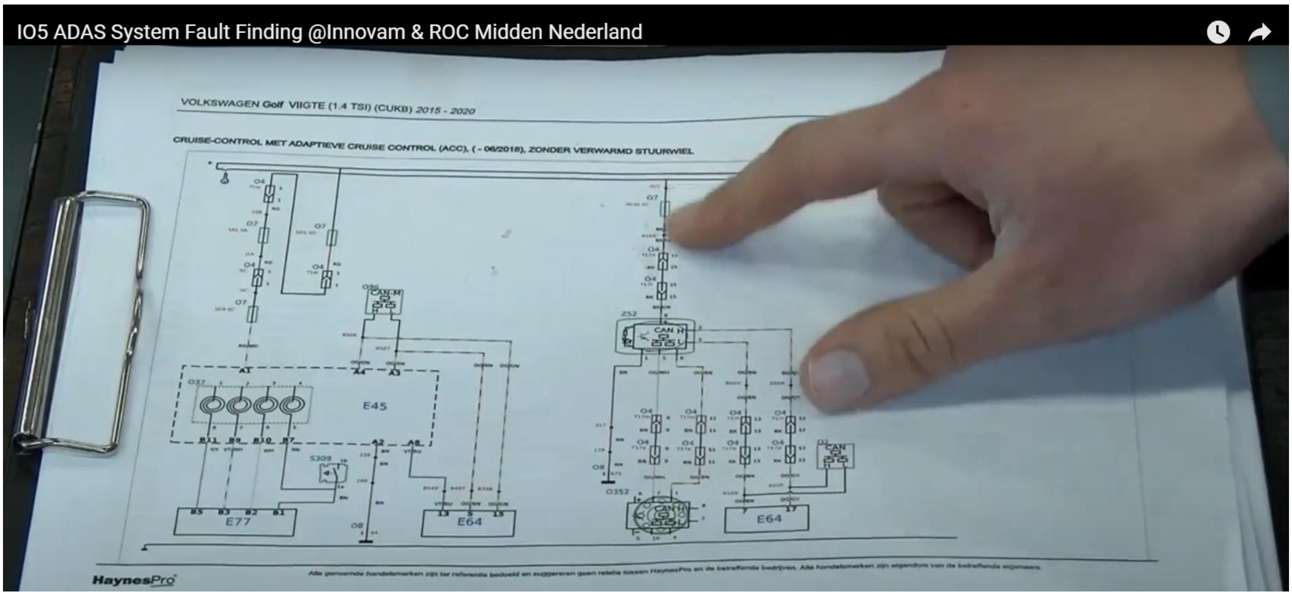


Procedure about repairing an ADAS component (vehicle radar) as shown in the video:

1) The trainee is given the task to prime the vehicle to detect any error message
2) A fault message appears: a failure is detected in the system
3) The Volkswagen OBD (Onboard diagnostic tool) is connected to the vehicle system and the scanning operations is started.
4) A fault is detected in the radar system
5) The trainer advices the learner to check the wiring system of the radar. The electrical wiring scheme of the radar is examined



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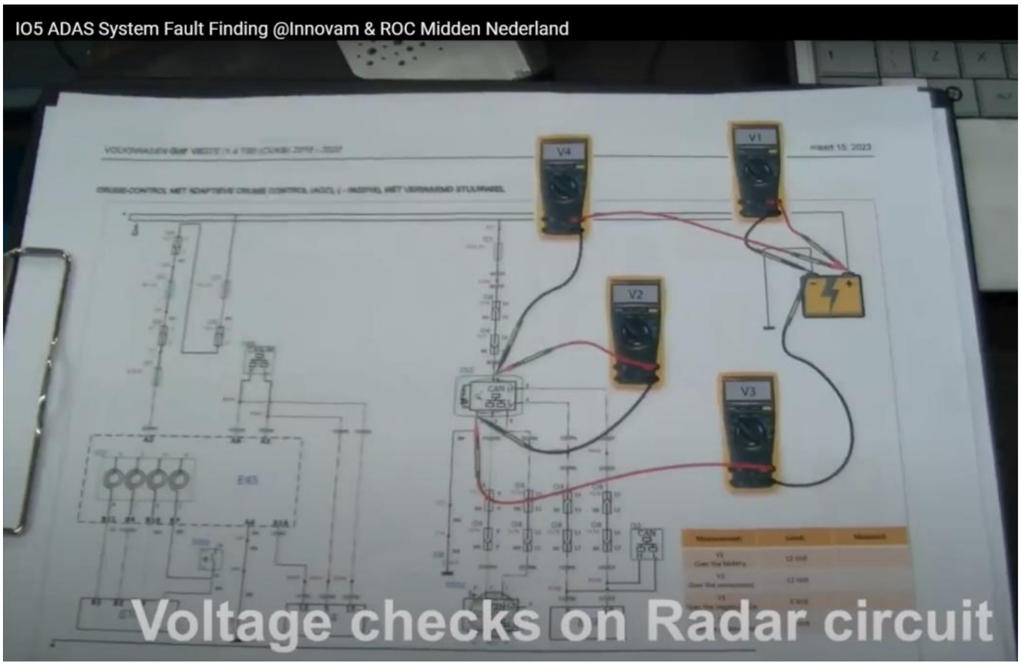
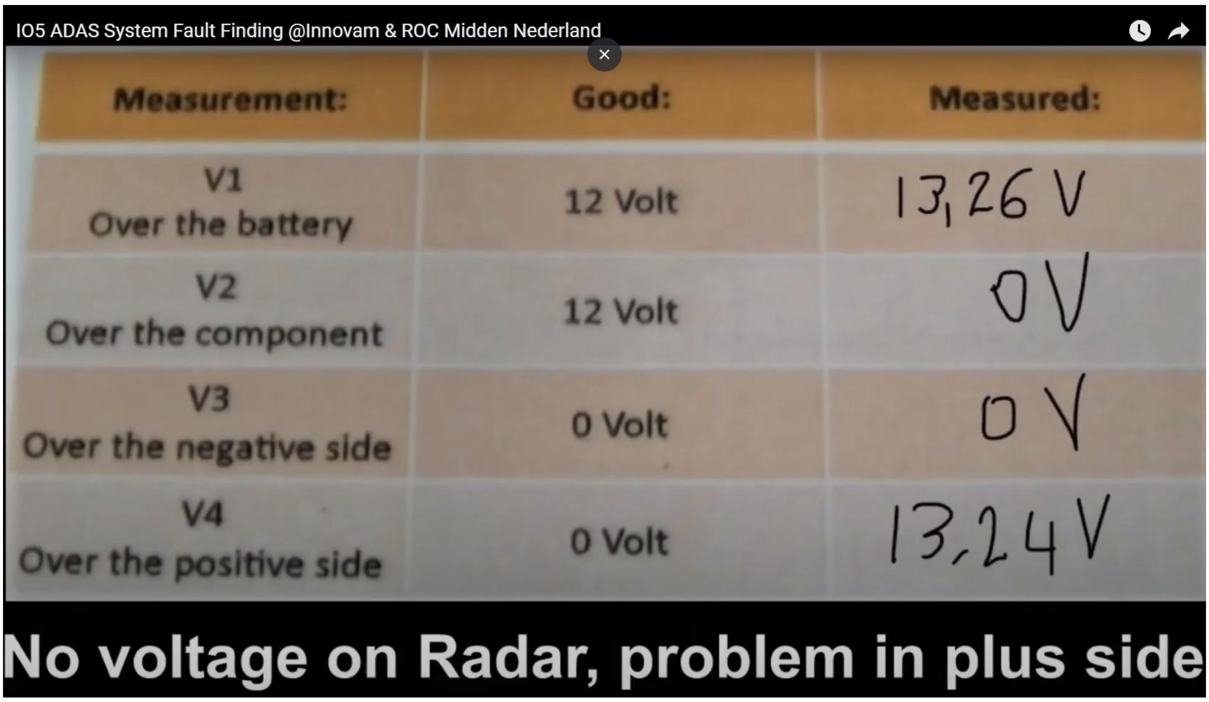
6) Voltage checks are performed on the radar electrical circuits

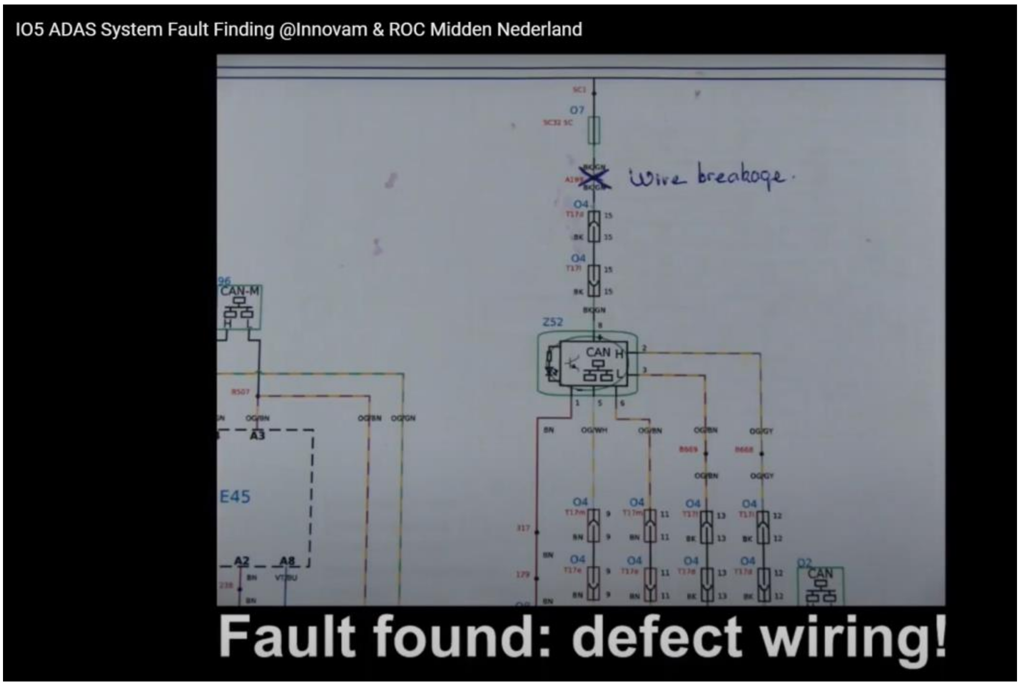


7) A scheme with the correct voltages that should be detected on each measurement terminal is provided to the trainee. The trainee is also given the task to perform all the measurements with a multimeter and to write the detected measurements down. As a result, no voltage in the radar is detected, so the trainee can infer the fault is on the plus side.



Measurement:	Good:	Measured:
V1 Over the battery	12 Volt	13,26 V
V2 Over the component	12 Volt	0 V
V3 Over the negative side	0 Volt	0 V
V4 Over the positive side	0 Volt	13,24 V

8) After carrying out all the measurements, the trainee will find out there is a breakage in the wirings of the vehicle's radar.



9) The student is then showed 3 main methods to perform wire repair:
    a. Cutting two edges of the broken wire, inserting a plastic tube connector and soldering the two pieces together. The piece is then reinforced through a Bunsen burner;
    b. Cutting two edges of the broken wire, twisting the two edges and merging them together to form a unique wire. The new wire is inserted inside a plastic tube connector which is then soldered through a Bunsen burner;
    c. Cutting two edges of the broken wire, twisting the two edges and merging them together to form a unique wire. The new wire is welded beforehand, and then inserted into a plastic tube and reinforced through a Bunsen burner.

10) The radar voltage is then checked after the repair: 13,12 Voltage, so the radar is ok
11) All fault codes are then erased from the OBD software interface
12) The VW vehicle is primed again: no fault codes!

EVALUATION FORM		
Students' Performance		
Students were engaged and interested	YES	*Remarks: Students had prior knowledge about ADAS through self-study*
Students were able to apply theoretical knowledge to practical tasks	YES	
Students were able to perform tasks	YES	*Remarks: guided instruction from the trainers was needed*
Students were able to work autonomously	In part	
Students were aware of safety procedures	YES	

Students were able to use diagnostic tools	YES	*Volkswagen dealer's diagnostic tools*

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	Achieved
Entry level knowledge and skills of the students	Adequate level to engage in the experimentation thanks to self-study beforehand More practice in reading electrical wiring diagrams would be beneficial.
Equipment & Tools	Used properly
Supervision & Tutoring	Effective *Remarks: Students were very eager to learn and listened carefully to the tips of the trainer. At this point in this training no points for improvement to indicate*
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete

Suggestion for further development	Practice on finding faults in ADAS systems
Missing skills for students:	Knowledge of organizational / business roles
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ Deeper or up-to-date knowledge of software or diagnostic tools
Further examples of topic-related troubleshooting problems	
EQF level 3	Repair basic faults in circuits of a ADAS component, i.e. camera or ultrasonic sensor.
EQF level 4	Troubleshooting of advanced problems in ADAS systems, for instance vehicle is braking suddenly without a known cause.
EQF level 5	-

Option 3 – Replacing parking brake pads on a Volvo XC40 recharge at Göteborgs Tekniska College, Sweden

This program trains learners to derive information about how to replace parking brake pads from the Volvo dealer's OBD – onboard diagnostic tool.

Through the OBD interface, the operator is able to access all the service functions available, choosing among a number of diagnostic sequences.

According to the E-mobility training suite available at Göteborgs Tekniska College, such topics might be tackled in the "Electrical machines and transmission" modules.

Module Title	Duration	Contents
EV Awareness	4 hours (theory)	• Environmental Issues & Constraints • Market development • Total cost of ownership • Technology involved
Battery System Overview	8 hours (theory and practice)	• Battery Technology • Electric Safety • Battery Management • Usage • Durability
Lithium-Ion battery system	16 hours (theory and practice)	• Cell Formats • Physical Chemistry • Supply Chain • System Design • Production
EV charging and power supply	12 hours (theory and practice)	• Modes • Behaviour • Infrastructure • Business Model • Power Components

Electrical machines and transmission	16 hours (theory and practice)	- Drives overview - Hybrid powertrain typologies - Circuit theory

Task: Replacing parking brake pads on a Volvo XC40 recharge.

The operations described in such procedure do not involve hand-on work on HV battery or lithium-ion cells, in fact the task is about putting the vehicle in service mode through Volvo OBD to proceed to replace the brake pads. Because of this, such procedure might be suitable even for EQF 3 level trainees who did not achieve the qualification of EiP (electrically instructed person).

DESIGN FORM	
Task	***Replacing parking brake pads on a HV vehicle***
Learning Objectives	Learning how to interact with EV during replacement work
Entry Level Knowledge (Theoretical)	Basic vehicle mechanic, use of hand tools, lift
Hard Skills involved	Basic vehicle mechanic, use of hand tools, lift
Soft Skills Involved	Knowledge about parking brake system. Able to read and understand procedures in workshop manuals and diagnostic tools.
Activities & Procedure required at EQF level (forecast)	EQF #3
Equipment & Tools to be used	Lift Hand tools Vida diagnostic tool

Other Professional Roles involved	EV teacher/employee
Supervision & Tutoring Activities	EV teacher/employee overview of processes during lesson, involving preparation for repair.
Expected Results / Solution	Students will have a better understanding of complete HV battery including which information that is available.

Procedure

1-First use a lift to prepare the work setting, then use a screwdriver to remote screw from the wheel and finally remove the wheel where you want to replace the relevant brake pads.

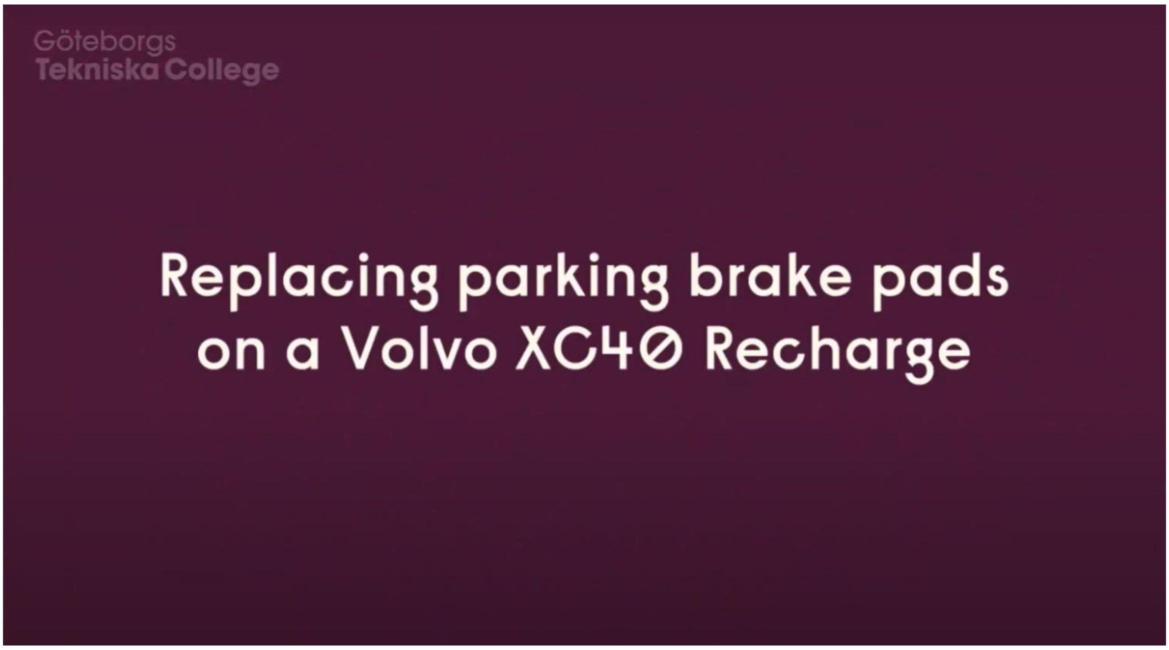
2-Connect the vehicle with the Volvo OBD tool, in this case Vida

3- Among the service functions, choose the diagnostic sequence “parking brake service position”

4-First out the vehicle into service mode, then inactivate the parking brake.

5-The parking brakes are now disconnected from the HV system. It is now possible to remove the worn parking brake pad and replace it with a new one.

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:



EVALUATION FORM

Students' Performance

Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	YES	
Students were able to perform task	YES	

Students were able to work autonomously	In part	*Deeper knowledge on basic car mechanics and diagnostic tools to increase autonomous work*
Students were aware of safety procedures	YES	*Safety shoes only*
Students were able to use diagnostic tools	In part	*Guidance was needed to correctly interpret the interfaces of the official dealer's diagnostic tools*

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	Achieved
Entry level knowledge and skills of the students	Deeper knowledge of basic car mechanics and diagnostic tools would be needed to increase autonomous work
Equipment & Tools	Deeper knowledge of the dealers' software would be needed to operate effectively
Supervision & Tutoring	Effective

Business Technicians	
Extent of transferability of the developed skills to the job market	Partial
Suggestion for further development	Deeper knowledge of the dealers' OBD
Missing skills for students:	Knowledge of organizational / business roles
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ More corporate trainers appointed to VET teaching would be needed
Further examples of topic-related troubleshooting problems	
EQF level 3	-
EQF level 4	-
EQF level 5	-

Option 4 – BMW e-car battery pack maintenance @ VAVM, Lithuania

This program was designed and tested by the Lithuanian Team, composed by the VET provider **VAVM - Vilniaus Automechanikos ir Verslo Mokykla** and **Moller Auto Lietuva**, Volkswagen & Audi national dealer, both based in Vilnius

At VAVM - Vilniaus Automechanikos ir Verslo Mokykla there are two main specialization running on:

-Automotive Mechanic (EQF 4)

-Automotive Electric Equipment Repairer (EQF 4)

Courses do not currently provide a specialisation in HEVs/EVs or avionics circuits, yet work-based training also include maintenance and diagnostics operations on hybrid or electric vehicles. Training modules include contents, knowledge and skills suitable to become the starting point which further e-mobility training can be based upon. Such topics include the following modules:

-Engines technical maintenance

-Transmission technical maintenance

-Automobile electrical equipment repair

-Engines electrical equipment

-Transmission electrical equipment

-Automobile comfort and safety electrical equipment

Task: HV battery pack maintenance

Since hands-on working on HV circuits is done, only trainees who passed a certified course as EiP (electrically instructed person) are allowed to carry out such procedures.

For correct procedures about how to operate safely on a EV/HEV, please check IO2 video of IG2 project. Furthermore, complete instructions about HV battery modules replacement are described in Output 4 video.

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DESIGN FORM	
Task	***E-car battery pack maintenance***
Learning Objectives	HV battery control unit fault finding, proper dismantle, repair, coding
Entry Level Knowledge (Theoretical)	Advanced knowledge of mechanics, electronics and software interfaces
Hard Skills involved	Correct way of using mechanical and safety tools. BMW diagnostic tester, multimeter, soldering station, gloves, mechanical tools and other specific tools. Properly managing hazardous materials (Soldering fumes)
Soft Skills Involved	English language
Activities & Procedure required at EQF level (forecast)	Troubleshooting control units inside HV battery Different IEC compliant diagnostic instruments needed for troubleshooting/repair Safety precautions around HEV/BEV, different requirements and hardware for different brands EQF 3 level
Equipment & Tools to be used	Multimeter, soldering station, basic disassembly tools, protective gear, wrench tool set, leak tester, BMW dealer's software, brushes.
Other Professional Roles involved	BEV/HEV Specialist/supervisor
Supervision & Tutoring Activities	Overview of processes during lesson, involved preparation for repair

Expected Results / Solution	Students will know how to diagnose problem, prepare for repair, fix tracks in control unit circuit

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:

The contents displayed in this video imply that the service plug connecting the HV battery and the e-vehicle has already been removed and the HV battery already removed too and put onto a service table.

Procedure:

-Removing the HV battery lid with EN IEC 60900 compliant work tools, able to insulate the operator from a voltage up to 1000 Volts in alternating current or 1500 Volts in direct current.

-One of the HV terminal plugs is fused and damaged

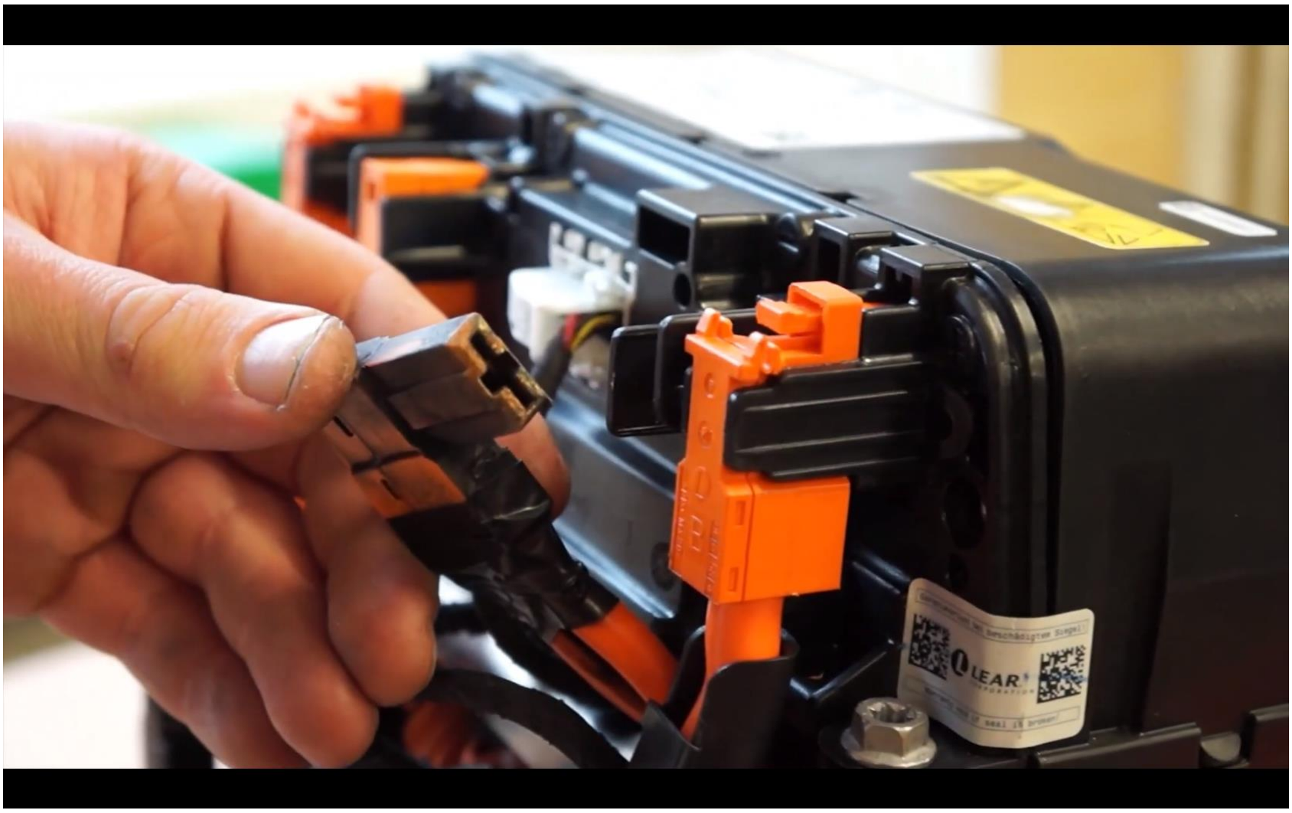
-Disconnecting all the battery plugs and accessing the battery modules place

-The suspected failed module is removed and voltage measurement is performed with a multimeter

-A new module is replaced and a new voltage test is performed

-The battery back is reassembled and the lid is put back on.

The battery is thus ready to be put back in the vehicle, which will be then connected again with the service plug and then primed.



EVALUATION FORM		
Students' Performance		
Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	YES	

Students were able to perform task	YES	
Students were able to work autonomously	In part	*Guidance from VET trainers was needed*
Students were aware of safety procedures	YES	*Electrically isntructed people only*
Students were able to use diagnostic tools	In part	*Guidance was needed to correctly interpret the interfaces of the official dealer's diagnostic tools*

VET Teachers & Trainers	
Learning Outcomes	Achieved
How to make it easier	Learning the correct operating procedure by video beforehand
How to make it harder	Causing faults in wiring, not in control units and letting students find problems by themselves
Expected results	Achieved
Entry level knowledge and skills of the students	The general level was adequate.
What knowledge or skills could be improved?	Knowledge about how to handle hazardous materials (soldering fumes, Li-Ion, etc.). More detailed explanation are necessary and students need to be more careful.

Equipment & Tools	Students used them partly correctly. Protective gears should be used more carefully.
Supervision & Tutoring	Effective
Potential improvements	It is possible to have multiple "dummies" for HV batteries. In that way more students could learn opening/closing/checking HV battery control units
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	It is still necessary to explain that faults may be not only inside battery or control unit but also in wiring. And wiring needs to be checked first.
Missing skills for students	Ability to put work procedures in practice
Development of teachers' role	More connections with the corporate sector
Further examples of topic-related troubleshooting problems	
EQF level 3	Charging/discharging HV system
EQF level 4	Checking HV battery leaks

EQF level 5	Checking HV battery control units inside HV battery

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Option 5 – HV battery system diagnostics within an hybrid vehicle @ ITS MAKER Academy, Italy

Such a program was run by the EQF 5 level courses within the Fondazione ITS Maker, based in Bologna, training Higher Technicians in advanced technology, mechatronics and automotive fields.

Within IG2 project implementation, there are namely two courses with e-mobility related contents:

- Higher Technician in Hybrid, Electric and Endothermic Engines (EQF 5)
- Higher Technician in Electric & Connected Car and Assisted Driving (EQF 5)

Since both profiles envisage high specialisation standards, attainable with a tertiary education course after the general upper secondary certificate (EQF 4), the current IO5 program is only targeting VET learners with prior knowledge and skills about:

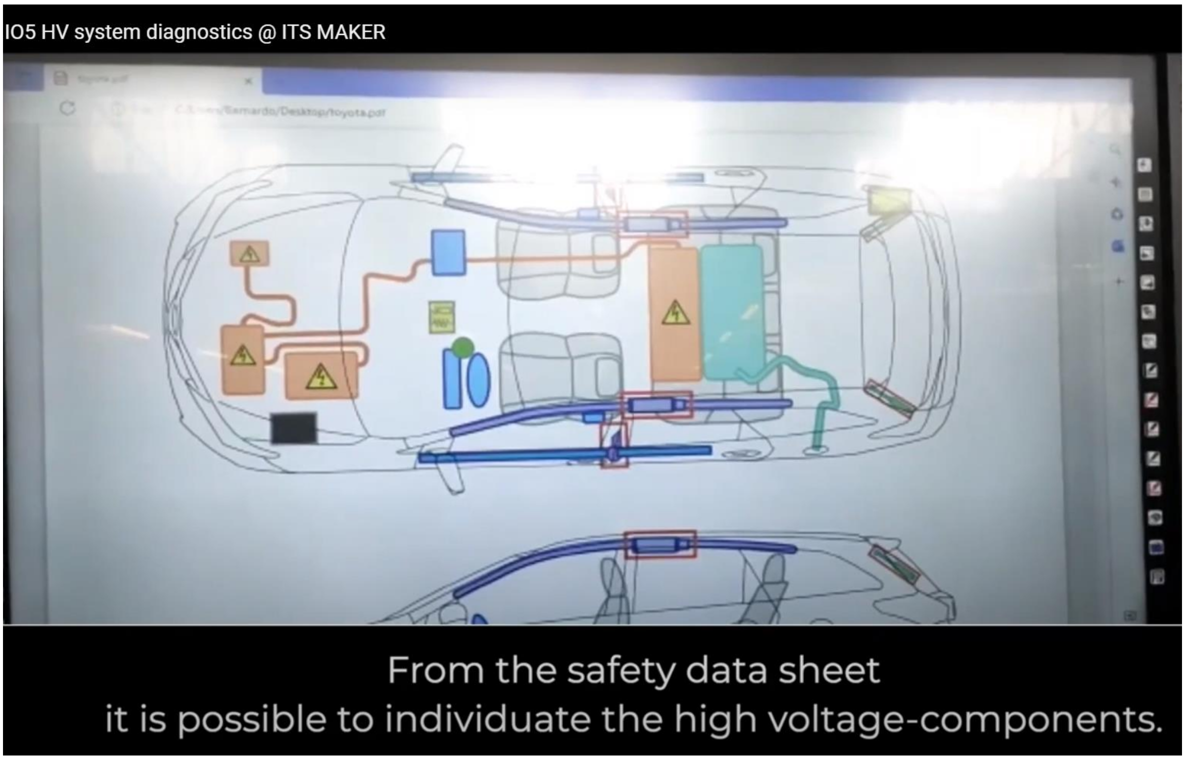
- Electrical schemes of vehicle circuits
- Electrical and electronic technologies and applications
- Installation and maintenance technologies and techniques

The IO5 task run by the Fondazione ITS Maker course in hybrid, electric and endothermic engines is about diagnosis of the HV system of a Toyota Auris Hybrid vehicle.

DESIGN FORM	
Task	***HV battery system diagnostics***
Learning Objectives	Knowledge of the main electrical and electronic circuits of vehicles in order to carry out correct maintenance in the event of faults.
Entry Level Knowledge (Theoretical)	Reading an electrical diagram, knowledge of laboratory diagrams and basic electronics,

Hard Skills involved	Holding a diploma/qualification as well as a minimum of internship experience in the automotive sector
Soft Skills Involved	Complying with safety regulations in the workplace, especially in case of electrical hazards.
Activities & Procedures required at EQF level (forecast)	Measuring and analysing electrical parts and repairing damaged and/or defective parts
Equipment & Tools to be used	Electrical measuring and diagnostic tools.
Other Professional Roles involved	Software programmers and hardware developers
Supervision & Tutoring Activities	Correct use of personal safety equipment and correct use of work tools.
Expected Results / Solution	Knowledge of the main electrical and electronic circuits of vehicles in order to carry out correct maintenance in the event of faults.

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:



Procedure:

1. Identifying HV components

First of all, the operator must be able to locate exactly where the HV battery is stored within the e-vehicle. Documentation can be found at Schede di Soccorso website, a multi-language Swiss website offering help files with the structure of the engine, battery location and other useful information about any car brand.

Italian-only similar website available at Scheda di Soccorso.

After the battery is located, it is possible to remove it according to the safety procedures described in Output 2 and Output 3 of the present IG2 project by ITS Maker Academy.

High-voltage components are clearly identified by the orange wires and signs - both in the engine compartment and inside the car).

2. Removal of HV battery

The HV battery, placed under the back seat, must be removed according to the safety regulations described by the relevant manufacturer (Toyota in this case). Before proceeding to the actual removal, the service plug must be removed to disconnect the battery from the HV wires. The operations must be executed with individual protection tools such as insulating gloves, googles and face shield to protect the operator from any electrical arc.

3. Checking voltage on HV battery

Use a multimeter and a 12-Volt battery to test the tool beforehand. Never proceed to measure the voltage on the HV battery, because it is not sure that the measurement is correct. So, first measure voltage on a low-voltage battery, then proceed to measure it on the HV battery, and later go back to the low-voltage battery. If the third measurement is the same as the first, all the measurement are correct.

Class 3 and 4 multimeter need to be used when high-voltage is involved.

4. Control of high-voltage battery relays

First, connect and check the positive relay, and then the negative relay. Voltage is 0 V, in this case the HV battery is not working. The remote control switches and voltage of electrical blocks must be tested too before any defective battery cell is replaced.

EVALUATION FORM		
Students' Performance		
Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	In part	
Students were able to perform task	YES	
Students were able to work autonomously	In part	*Guidance was needed from the trainer*

Students were able to find faults	In part	*Guidance was needed from the trainer*
Students were aware of safety procedures	YES	
Students were able to use diagnostic tools	In part	*Guidance was needed to correctly interpret the interfaces of the official dealer's diagnostic tools*

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	In part: it takes more practice to gain experience
Entry level knowledge and skills of the students	Partly adequate. Learners are still lacking practical skills
Equipment & Tools	Deeper knowledge of the dealers' software would be needed to operate effectively
Supervision & Tutoring	Effective

Business Technicians

Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	-
Missing skills for students:	Ability to apply work procedures in the learning environment
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ Deeper and up-to-date knowledge of dealers' software or diagnostic tools.
Further examples of topic-related troubleshooting problems	
EQF level 3	Applying safety procedures on voltage vehicles
EQF level 4	Diagnosing assisted driving systems and calibrate them
EQF level 5	Diagnosing anomalies on electric vehicles with ADAS

3. Collecting VET learners' feedback

As stated in the IO1 paper about designing a pilot Train-the-Trainers program about e-mobility, a relevant part of the program itself relies into collecting the learners' feedback about both their appreciation and their self-evaluation about the training experience.

Questions might vary according to the learning objectives of the experimentation and the EQF level of the VET provider, but on a general rule the following criteria should be met in order to administer feedback questionnaires to measure the impact of the training activities:

-forms should be collected anonymously to make sure respondents are free to express their sincere and honest feedback about the training program, either on a paper or digital format;

-questions might be multiple-choice or on a scale, but in any case some room for further comments or remarks should be left;

-the extent to which the training workplace helped students develop e-mobility skills should be assessed;

-the effectiveness of the mentoring or supervisory activities should be assessed;

-the extent to which prior knowledge and skills were allowed learners to make the most out of the training program should be assessed;

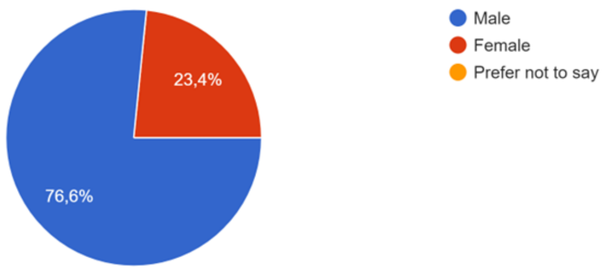
-the perception, on the learners' side, of actual development of e-mobility skills should be assessed;

-the extent to which learners think to be suitably prepared to transition to the job market.

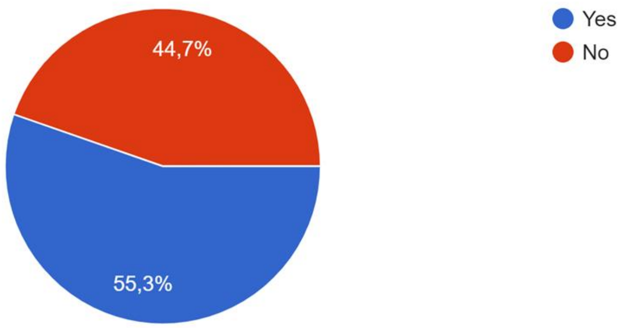
Examples of the collected feedback can be seen from the charts below, which report genderless aggregate data from all the countries and EQF levels involved.

Answers with scale from 1 to 5 mean that respondents were asked to rate the sentence in the questions with a score from 1 (absolutely not) to 5 (absolutely yes).

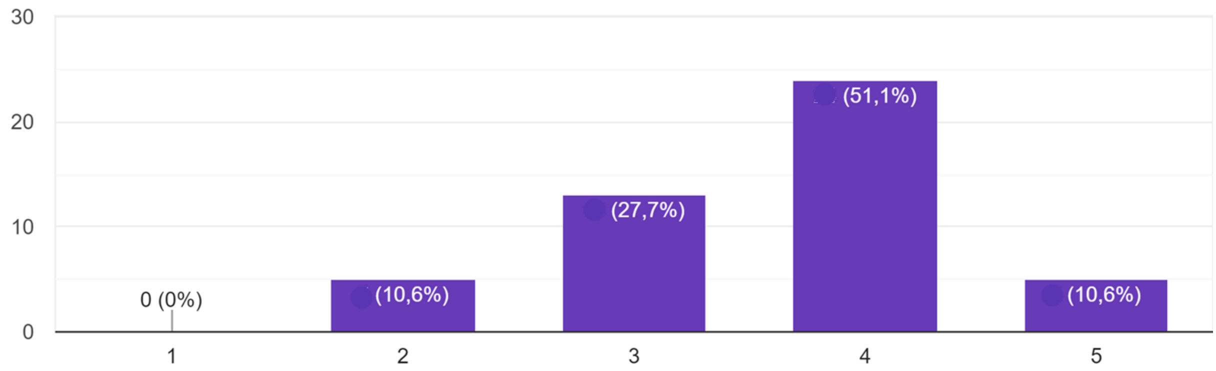
Your gender



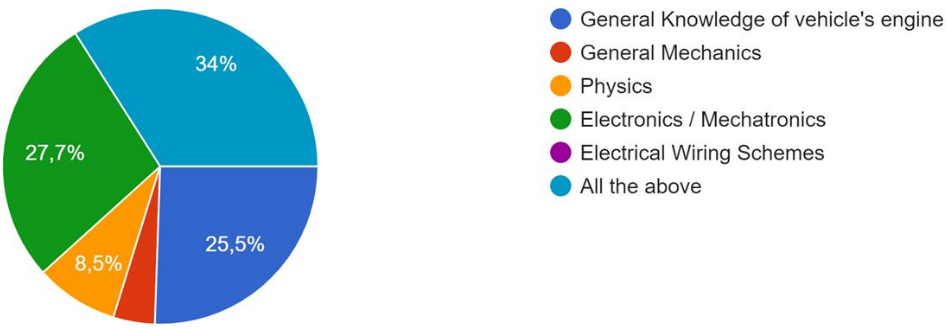
I already took classes in electro-mobility or HEV/BEV before participating in the project



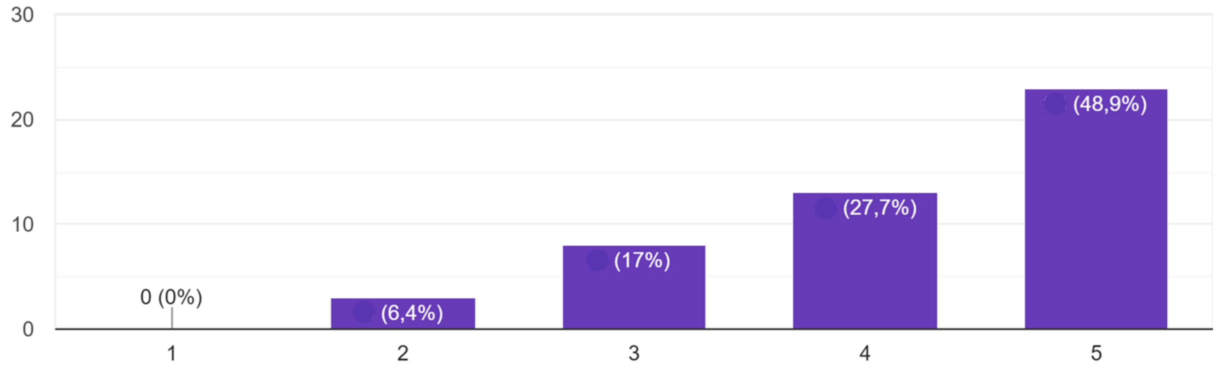
I think my previous knowledge & skills level was enough for me to take part in HEV/BEV testing



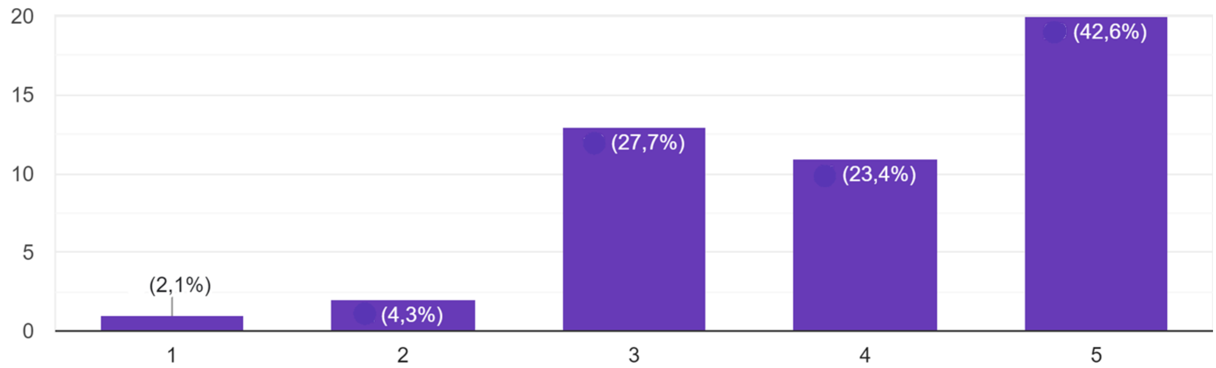
Which of the following was most helpful for you to make the most out of the HEV/BEV testing?



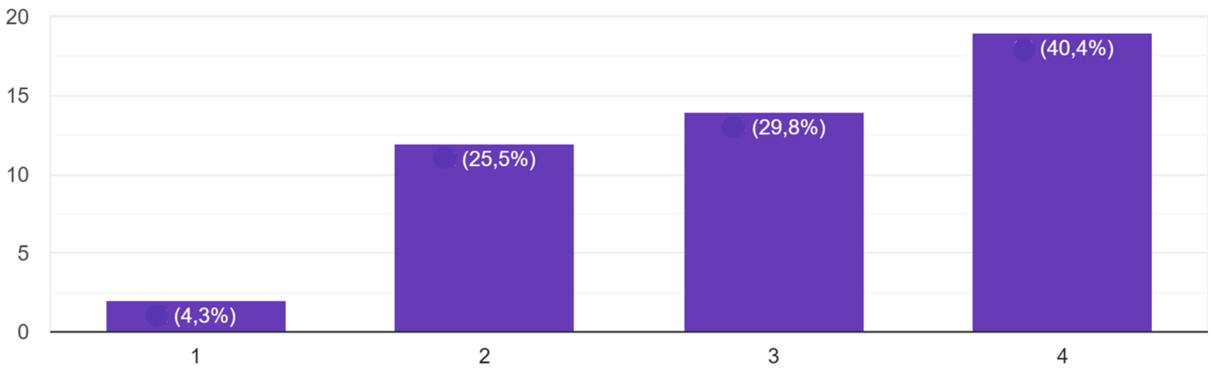
After the testing, I think I developed knowledge and skills about how a to work safely on an HEV/BEV vehicle



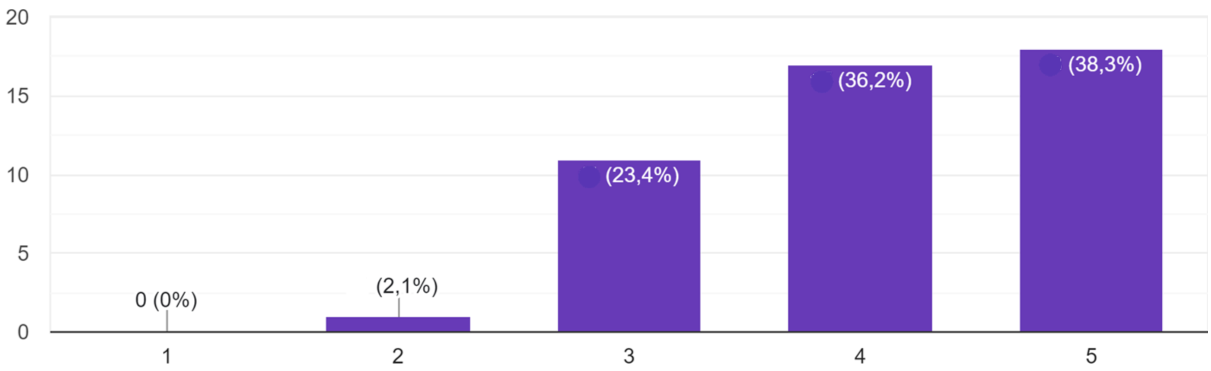
I think I can read electrical circuit wiring schemes



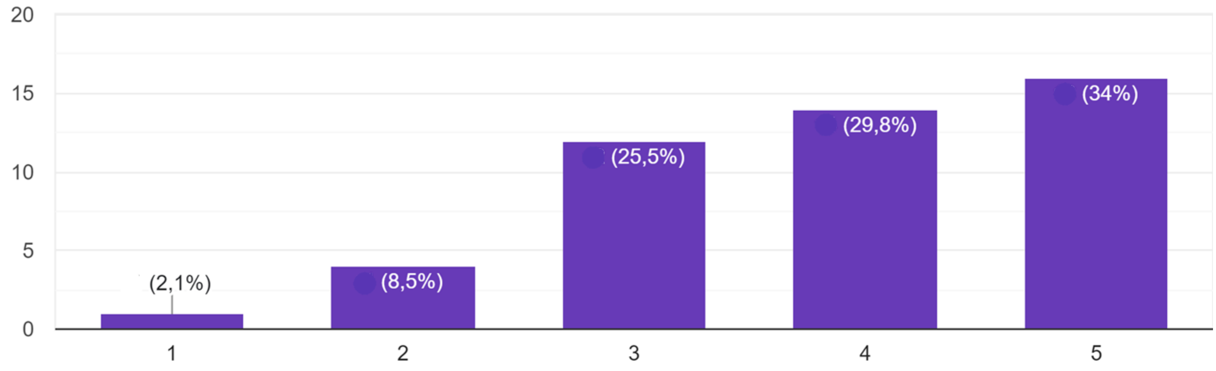
I developed knowledge and skills about ECU - Engine Control Units circuits damage & repair



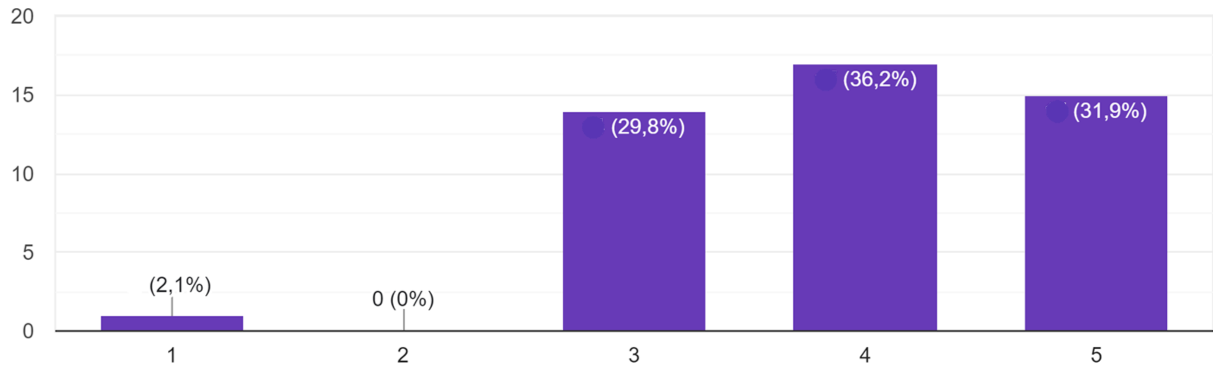
I developed knowledge and skills about ADAS calibration and diagnostics



I developed knowledge and skills about how to perform failure diagnosis & repair in a EV/HEV system



I developed knowledge and skills about assisted braking systems in a EV/HEV system



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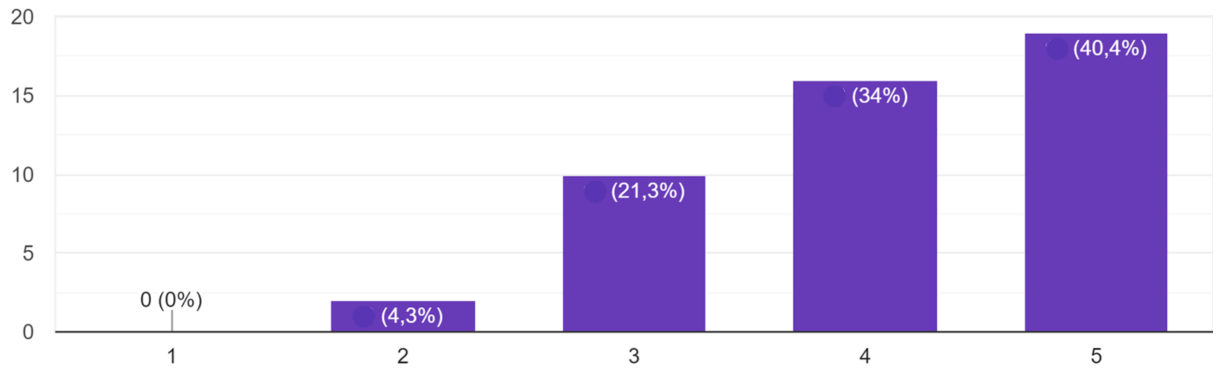
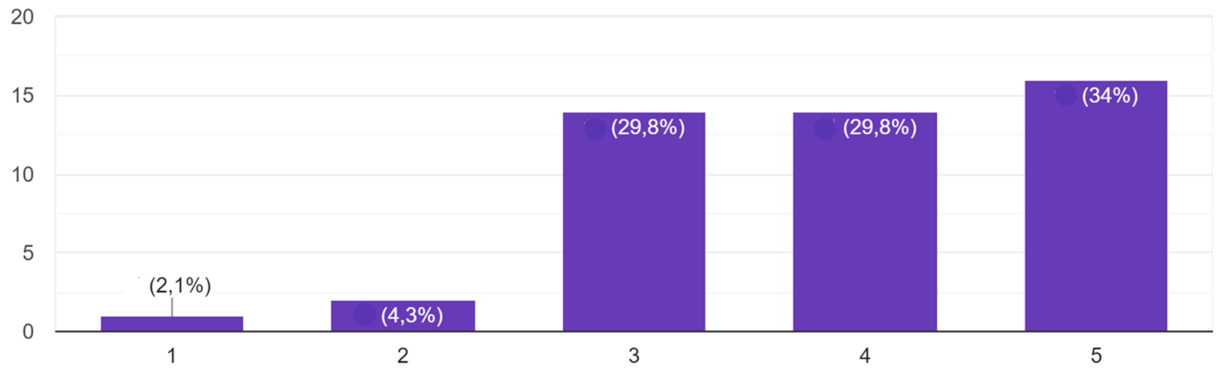
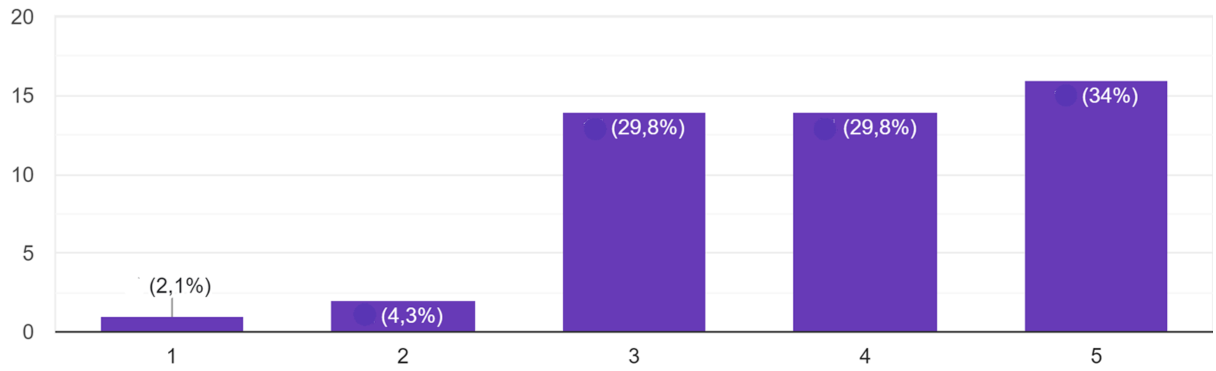
I developed knowledge and skills about EV/HEV battery

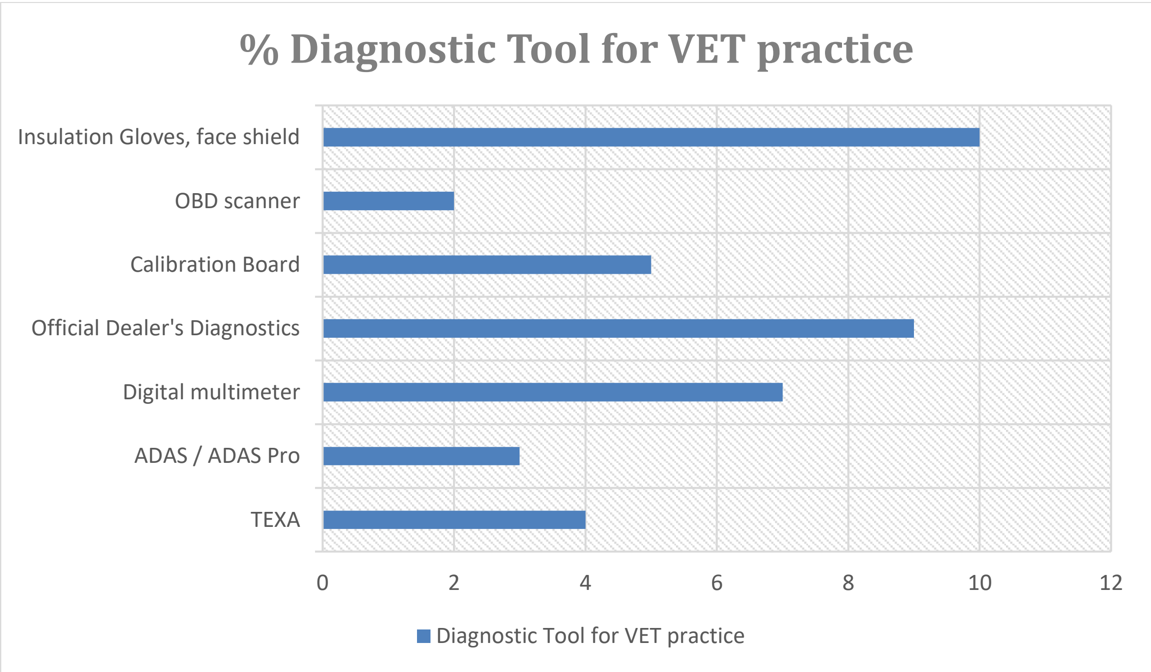


I developed skills in using EV/HEV diagnostic tools



I developed skills in using EV/HEV diagnostic tools





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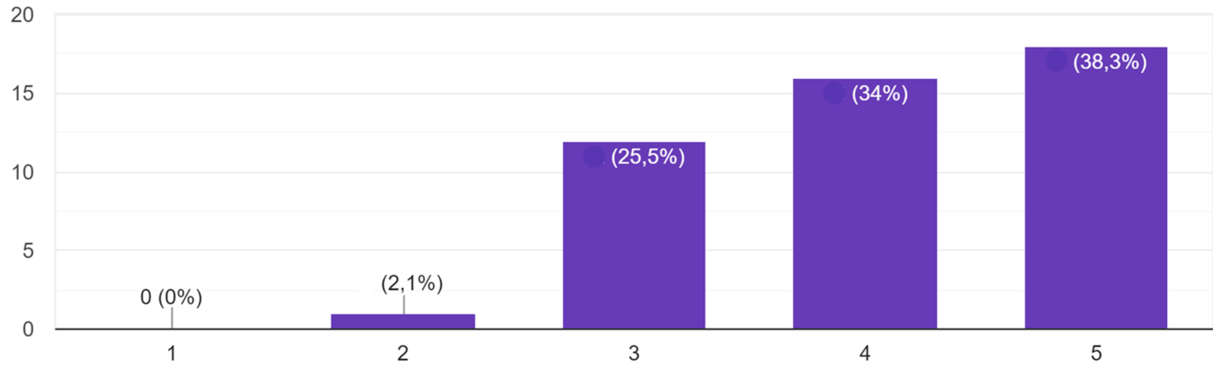
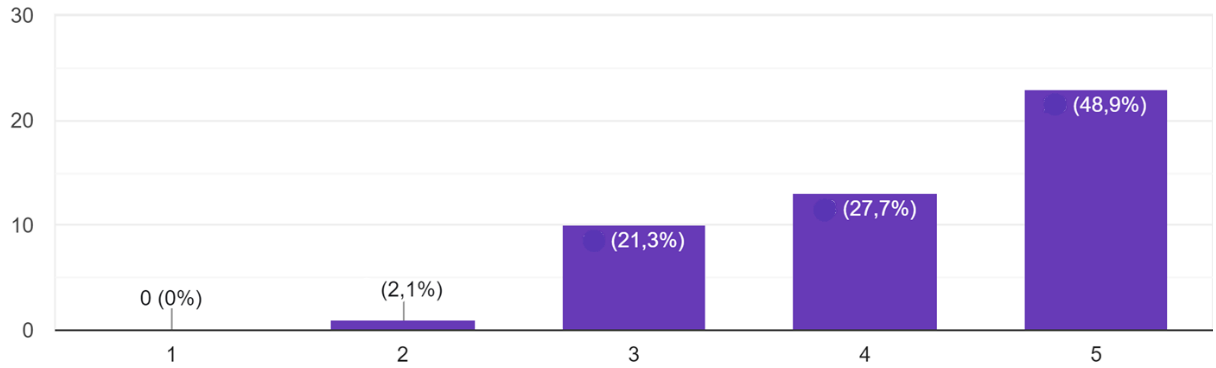
I think I have better ideas about how a company workplace or a production plant or car workshops works



Thanks to the testing, I think I am better prepared for the automotive job market



Conclusion: who is this paper for?

This paper represents the outcome of Intellectual Output 5 of “Innovation Garage of Garages” Erasmus+ project, aiming at developing green skills for the automotive sector at VET level.

The specific goal of such a paper is to provide guidelines for VET teachers and trainers willing to introduce hybrid or electric engines, high voltage and their components as a modular or integrated path within mechanics or automotive courses.

Multiple actors co-designing the training contents, the workplace layout and tools, as well as the organisational details of the didactic methodology (roles of trainers, facilitators, evaluation and assessment criteria, is the special footprint of the project. Since “Innovation Garage” is a worldwide methodology to introduce bottom-up multi-stakeholders innovation over the workplace premises, what this project is aiming at is renovating the way which “workshops” or “garage” training is usually performed.

So, this is just a proposal that needs to be customised with specific contents according to the target learners and the regular training courses within a VET organisation.

IO5 paper is suitable both for teachers and trainers at I-VET level (schools, training centres for young people or adults) from EQF levels 3-4, or even for H-VET at EQF 5 level (tertiary education other than university level). Nonetheless, e-mobility training can involve managers, technicians or trainers at company level - either at production houses, or repair workshops, or dealers, whenever workers need to develop or upgrade their skills about the management and maintenance of HV batteries, of HEV/EV vehicles and their components.

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Project no. 2020-1-IT01-KA202-008555

"Innovation Garage of Garages"

IO6 – Intellectual Output 6

Training programme related to customer care and first intervention procedures, based on the work-based learning methodology located inside the innovation garage

Output Type: Open / online / digital education

OER – Open Educational Resource

The project is funded by ERASMUS+ Programme of the European Union. The content of this material does not reflect the official opinion of the European Union, the European Commission and National Agencies. Responsibility for the information and views expressed in this material lies entirely with the author(s). Project number: 2020-1-IT01-KA202-008555

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Training Program on customer care and after sales of EVs/HEVs

Language: English

Author:

Innovation Garage of Garages Partnership

Coordinator: Cisita Parma scarl, Italy

Co-funded by the Erasmus+ Programme of the European Union

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Intro: the learning model

Since VET providers maintain close cooperation with the industrial sectors, especially within the automotive field, workplace training is the most valuable asset that educational institutions hold to develop job-related skills, facilitating the learners' transition into the labour market.

In this view, the "Innovation Garage of Garages" project (named "IG2" below), holds the purpose to bring VET providers and automotive companies together (either construction houses, OEMs manufacturers, dealers, car-repair workshops) to co-design training paths & learning environments suitable for the development of green mobility skills, in terms of:

a-learning goals & contents;

b-layout of the training workplace;

c-tools, machinery and equipment.

According to the panorama of the green skills and job profiles within the Automotive sector, identified in the IO1 paper, the main 5 work processes that IG2 project deals with are:

IO2: Installation & Assembly of EV/HEV engines

IO3: Maintenance of EV/HEV engines

IO4: Configuration & calibration of Avionics systems in e-vehicles

IO5: Maintenance of Avionics systems in e-vehicles

IO6: After-sales & customer care assistance as well as road-rescue and safety procedures related to EVs/HEVs

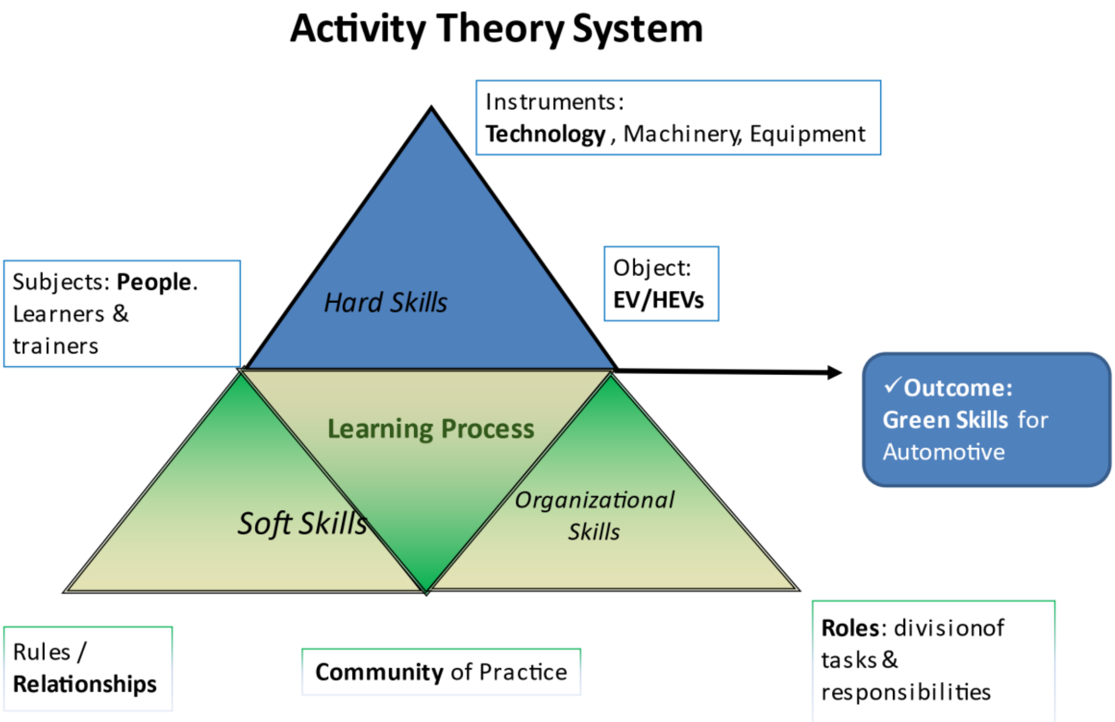
The training environment should make practical learning accessible and inclusive, and students should learn from work processes and organizational structure, as well as use technological assets that are the closest possible to the real workplace layout.

This is what IG2 partnership agreed to call "situated learning", identifying the dynamics of a training environment equipped with technological tools, where learners are immersed into a productive process governed by supervisors performing a mentoring and leading role, aimed at manufacturing a given product.

The learning model inspiring the project methodology is the "Activity Theory" framework by Yrjö Engeström (1987/2015), representing the third generation of academic researchers studying the topic, after the contributions of cultural-historical psychology from the Russian Vygotsky to Leontyev.[1]

[1] For a very introductory documentation over the "Activity Theory" system please see:

- Andy Blunden "Engeström Activity Theory and Social System", 2015



According to such model, the overall learning process is composed of two main dimensions: the immersive experience of actually doing some activity or of producing a real product within a given environment, such as the school lab or the training facility, or workplace itself. This is the dimension where the e-mobility hard skills are being developed, thanks to the interaction of 3 main elements: people (learners & trainers) as *subject* of the process; tools (such as technology, equipment and machinery) as *instruments* making the learning process come true; the *electric/hybrid vehicle* or one or more of its components, as the *object* of the learning process itself. The outcome of the interaction of such 3 elements is the expected learning goal itself for the relevant testing, or, more generally, the green skills for the automotive sector.

Underneath the upper triangle, the Activity Theory puts the hidden or intangible part of the learning process, which is related to the development of all the soft skills implied by interacting within a complex organisation of people. This is what happens to workers in a company, but workplace learning or workplace simulation actually reflects the very same dynamics. As a matter of fact, within an automotive production site or within a car repair workshop, for example, workers are assigned different roles, responsibilities and tasks which actually shape the interpersonal relationship happening over there. VET learners, either in their initial training at school, or involved in lifelong and continuous training at work, are immersed in a community of

- Oliver Ding, [Yrjö Engeström: the Activity System Model](), 2021

practice, where knowledge, skills & behaviours are shared, promoted, rewarded or even confuted or rejected.

IG2 project, by bringing together VET providers and companies, aims at co-designing learning experiences for the development of e-mobility skills, keeping in mind such behavioral and organizational learning model.

1. Referencing Output 6 e-mobility skills to the current job qualification frameworks

Output 6 of the IG2 project is focused on the development of skills related to the customer care or after sales services, as well as to the road rescue and safety procedures in case of crash, failure or fire events, related to electric or hybrid vehicles.

According to IG2 partners, such tasks can range from simple and basic ones, attainable from EQF 3 operators or even lower, e.g. C-VET operators achieving EQF2 vocational qualifications, to technical or supervisory roles (EQF 4 - EQF 5).

Output 6, outlining the train-the-trainers program for VET teachers willing to introduce e-mobility in their didactic courses, collects the job qualifications in the automotive sector according to the ESCO framework and from the job-profiles and skills card classified by the Erasmus+ Sector Skills Alliances DRIVES 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B (for the general automotive sector) & ALBATTS 612675-EPP-1-2019-1-SE-EPPKA2-SSA-B (specifically for the battery sector).

According to such classifications, Output 6 refers to the following job roles matching the EV/HEV engine assembly operations:

	DRIVES Development and Research on Innovative Vocational Education Skills	albatts
Motor vehicle assembler		EV Automotive Repair and Inspection Personnel
Automotive Electrician		
Electrical Cable Assembler		
Electrical Equipment Assembler		
Electrical Equipment Inspector		
Electrical Mechanic		
Electrical Supervisor		

Automotive Battery Technician		Battery Manufacturing Technician
Battery Assembler		Battery Module Assembly Technician
Battery Test Technician		Battery Quality Technician
		Battery Recycling Technician
	Predictive Maintenance Technician	
	Functional Safety [Engineer/Technician]	
	Sustainability Manager	
Automotive Test Driver		
Fire Service Vehicle Operator		
After Sales Service Technician		

Among all the e-mobility related job qualifications that ESCO, DRIVES and ALBATTS put together, the one listed above are the ones that are at least partly relatable to the training programs that were designed and tested by the IG2 VET providers' consortium, and that will be described in the chapters below.

2. Designing, testing and evaluating results of training programs about the after sales, customer care and road rescue of EVs/HEVs

During the Pilot Phase of IG2 project (Output 1), partners agreed that the basic structure of any topic-specific program about e-mobility should start with a joint business-VET design phase, including:

– identifying learning objectives,

– setting knowledge or skills entry requisites for VET learners,

– identifying the work procedures to implement,

– setting the training workplace layout and necessary tools/equipment,

– deciding on the expected outcomes of the troubleshooting,

– establishing supervisory and tutoring roles

VET providers were not assigned prescriptive rules about which relevant topic should be chosen for a training program about EV/HEV engine assembly or installation. Multiple reasons usually affect the choice of the specific topic to focus on, and the following criteria should be taken into consideration while evaluating the potential options:

a) whether or not the VET provider is already including specific training modules or contents about EVs/HEVs in the institutional offer;

b) the EQF level of the training course where e-mobility should be taught or introduced for the first time;

c) the general level of technical knowledge & skills of the target learners as well as their behavioural / communication skills and/or their potential fewer opportunities profile

With regards to point a), this is absolutely the most significant and diriment criterion that should guide the choice of VET trainers: are learners already trained about safety precautions around HV batteries and electric or hybrid engines? Are learners already able to read the electrical schemes of the car? Are they already familiar with the structure and components of internal combustion engines whatsoever?

If this is the case, it is probably a good choice to delve into EV/HEV engines specific topics such as electrical insulation or HV battery modules checks, or calibration of ADAS systems, on-board cameras and radars. On the opposite side, learners who are not trained about electrical risks must never work hands-on with HV batteries. This happens with upper secondary education courses at EQF 3 or EQF 4 levels, where students work just on the mechanical part of engines. In this case, in the first place mandatory electrical safety courses must be attended from students, and demo classes about HV batteries where trainers show the correct

battery management procedures without students being involved, or using electronical panels simulating the engine mechanism or the switches of sensors regulating the circuits of the car, are good examples of introductory activities.

Furthermore, VET trainers should take into consideration the general profile of the target learners involved:

-EQF level of the training course and previous knowledge & skills gained by students

-the age of the learners: is it young people in initial learning or is it workers engaged in an upskilling or re-skilling course within C-VET training paths?

-the general lifelong background of the students involved: is there any type of potential disadvantage represented in the learning group?

This might range from physical or cognitive disabilities, to migrant background or language barriers preventing students from a full exploitation of the learning opportunities, or even age barriers, in the case of underqualified over-50 workers in need of a skill upscale to prevent job loss. In any of such cases, special arrangements should be envisaged by trainers in order to choose the most inclusive and barrier-free training environment possible. In case any learner has a physical disability, the workplace should be designed in a way that the learner is safe throughout the testing, yet he or she can either see the work procedures or operate some of them according to both the work safety procedures and to what the medical conditions allow. In case the learner has a mild cognitive disability, VET trainers should design the experimentation assigning tasks to small students' teams with an appointed leader with a distributed share of duties, so that everybody can be involved in the experimentation with different level of difficulty or responsibilities.

Team work and practical learning is especially recommended and effective in case of migrant learners with little command of the local language, as graphic or synthetic work procedures help understand topics or tasks quicker than a theoretical frontal class.

Evaluation. As a part of O1 train-the-trainer program results, IG2 project partners established a protocol for the evaluation of the work-based testing, to assess to which extent the program itself was successful for VET learners to develop e-mobility skills. Such assessment is a simple form with questions addressed both to VET teachers or trainers, and to business technicians, since the workplace training should be co-designed on both parts.

Teachers or trainers should assess:

– whether or not the learning goals have been met,

– whether or not the work-based testing delivered the expected outcomes,

– to which extent the expected knowledge and skills have been gained by the students or not,

– whether or not the diagnostic tools were used properly,

– whether or not the supervisory and tutoring activities were adequate to provide learners with the guidance they needed.

When relevant, teachers might also provide additional information about the main difficulties overcome, which tasks were missing or not correctly performed during the experimentation, as well as suggestions on how potentially making the experimentation easier or harder according to the learners' profiles.

On the other hand, business technicians should assess to which extent the knowledge and skills that students developed thanks to such a training experience are indeed useful and transferable to the job market. Furthermore, business technicians might as well provide further examples of troubleshooting and diagnostics experimentations on similar topics, that they believe might help learners develop missing skills about working on EVs/HEVs at different EQF levels.

Let's see examples of the training programs that each country team participating in IG2 project designed & tested.

Option 1 – Cause of hazard in operation and maintenance of battery systems @ Göteborgs Tekniska College (Sweden)

This resource provides a brief and summative theoretical lesson about a huge topic: how to handle lithium-ion batteries and how to prevent external or internal factors causing hazards for both the human health & safety and the natural environment.

According to the E-mobility training suite available at Göteborgs Tekniska College, such topics might be tackled in the “Battery system overview” and in the “Lithium-Ion battery system” modules.

Module Title	Duration	Contents
EV Awareness	4 hours (theory)	● Environmental Issues & Constraints ● Market development ● Total cost of ownership ● Technology involved
Battery System Overview	8 hours (theory and practice)	● Battery Technology ● Electric Safety ● Battery Management ● Usage ● Durability
Lithium-Ion battery system	16 hours (theory and practice)	● Cell Formats ● Physical Chemistry ● Supply Chain ● System Design ● Production
EV charging and power supply	12 hours (theory and practice)	● Modes ● Behaviour ● Infrastructure ● Business Model ● Power Components
Electrical machines and transmission	16 hours (theory and practice)	● Drives overview ● Hybrid powertrain typologies ● Circuit theory

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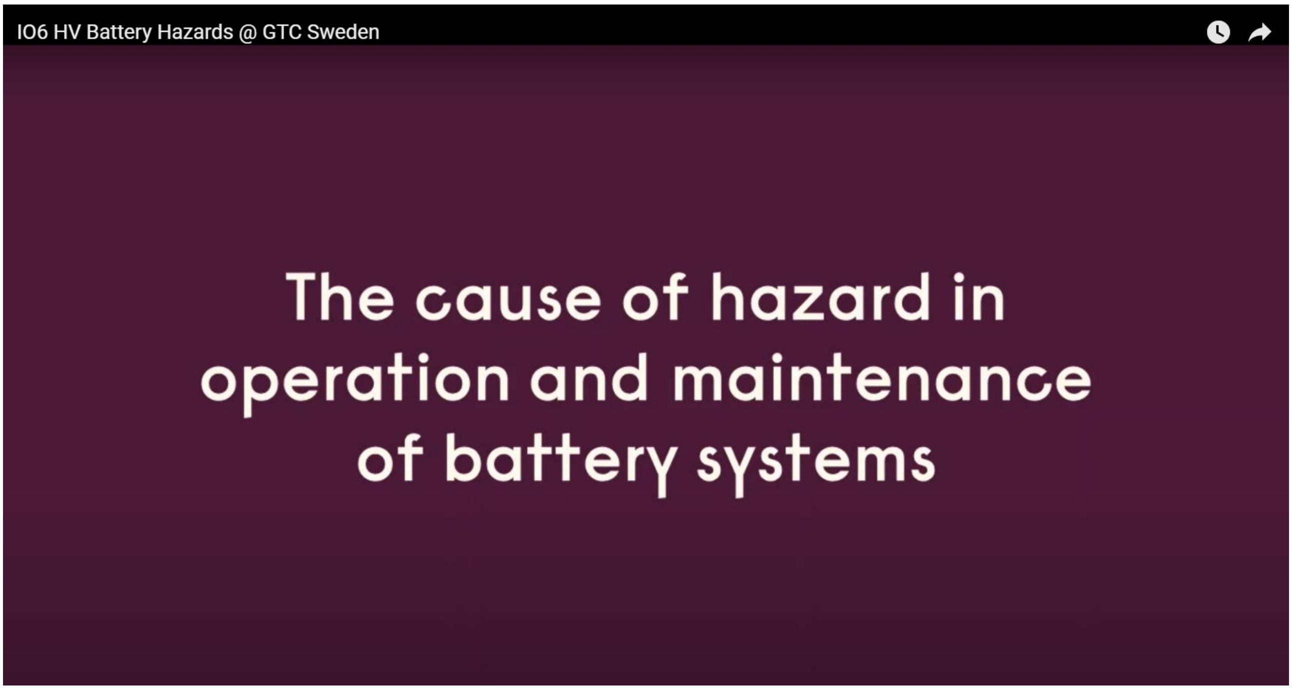
This is a totally frontal lesson. It implies developing knowledge about the physics and the chemistry affecting HV batteries and their modules and cell. On the other hand, it does not imply any practical skills or hands-on work. Because of the advanced contents about chemical reactions, chemical components and the law regulating electrical fields, target learners for those contents go from EQF 5 and above. Nonetheless, given the fact that the program is totally theoretical, it is suitable even for EQF 3 learners without any work-safety qualification about electrical works.

Task: Understanding the cause of hazard in operating with battery systems

DESIGN FORM	
Task	**Cause of hazard in operating with battery systems**
Learning Objectives	Safety and security concerning Lithium-ion battery system; How do the batteries work; Power losses concerning heat; Environmental impact of battery cell commodities.
Entry Level Knowledge (Theoretical)	Basic knowledge about chemistry; Able to read and understand procedures in battery system; Manuals and diagnostic tools.
Hard Skills involved	Ability to operate a diagnostic tool. Ability to identify real physical components. Knowledge about Lithium-ion cell
Soft Skills Involved	Ability to read and understand procedures in workshop Manuals and diagnostic tools on Lithium-ion battery system
Activities & Procedure required at EQF level (forecast)	EQF 5
Equipment & Tools to be used	Diagnostic tool (Vida)
Other Professional Roles involved	EV teacher/employee

Supervision & Tutoring Activities	EV teacher/employee overview of processes during lesson, involving preparation and evaluation.
Expected Results / Solution	Students will have a better understanding of complete HV battery including the cause of hazard in operation and maintenance of battery systems.

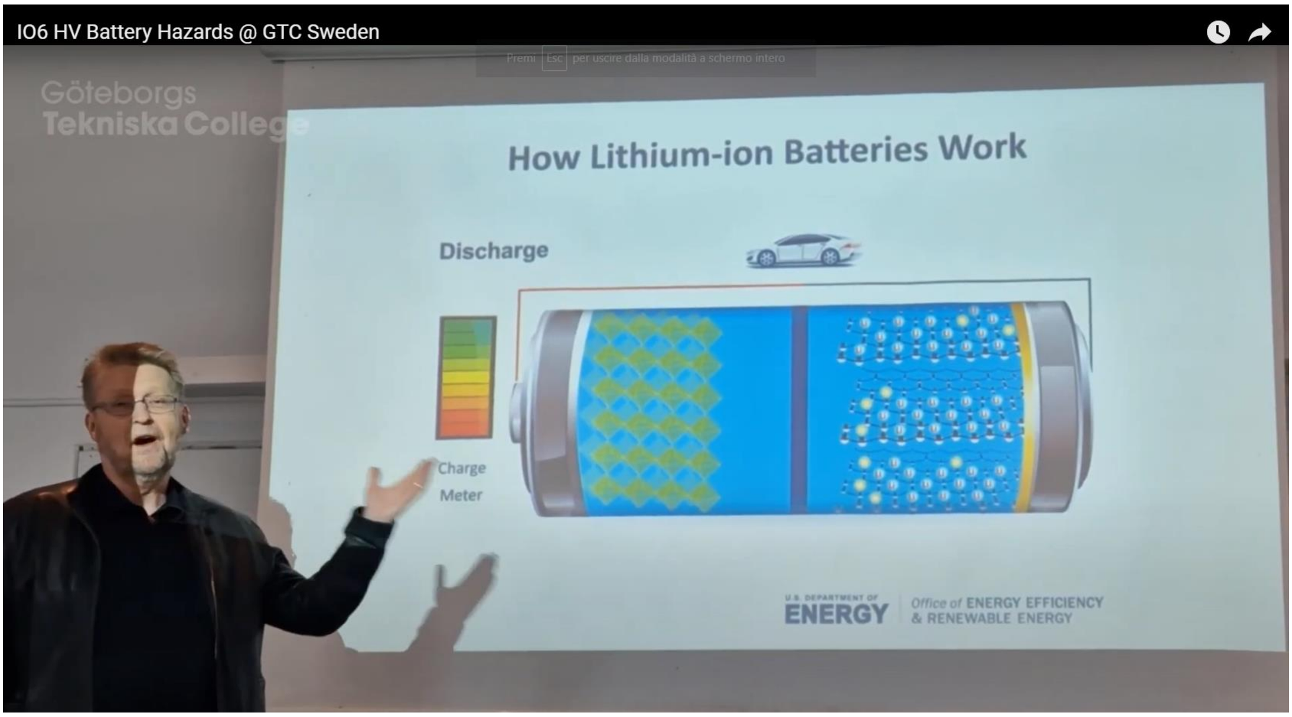
The program was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:



Index of Main Topics

The speaker in the video is Mr Fredrik Hannerz, teacher of electro-mobility at Göteborgs Tekniska College and expert in physical and chemical reactions within batteries.

1)The chemical structure of a cell composing a module of a lithium-ion battery



2) Chemical Substances inside a lithium-ion battery cell

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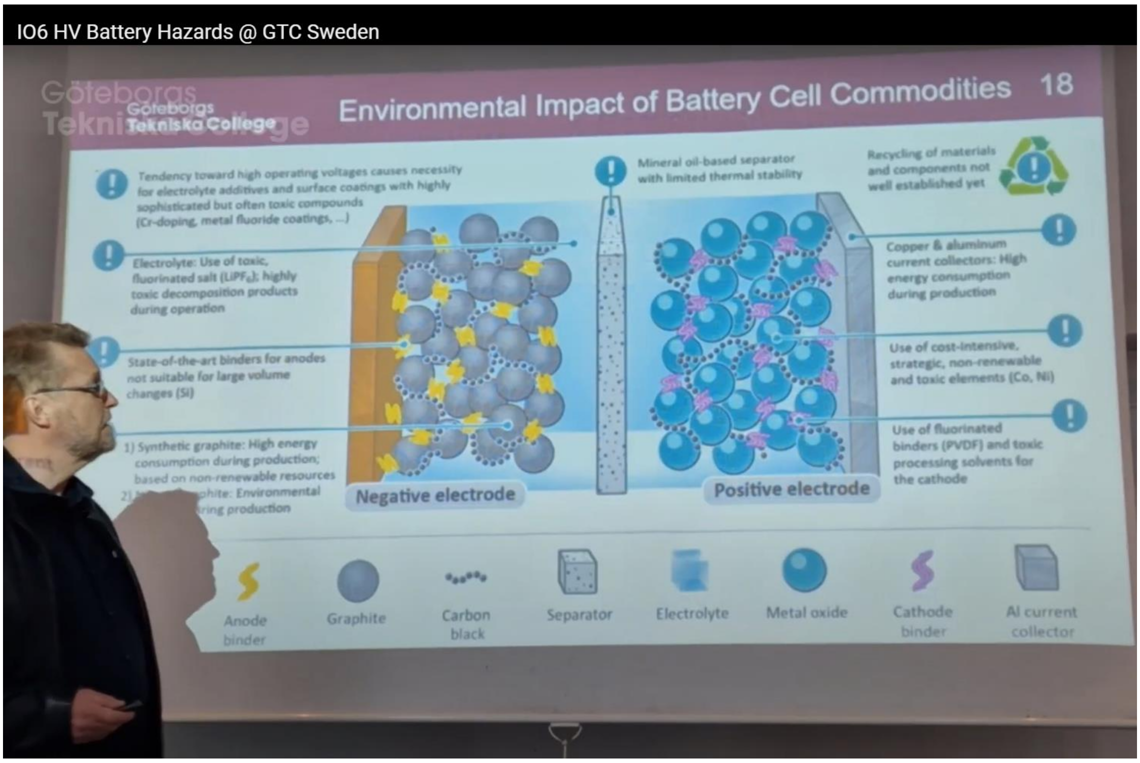
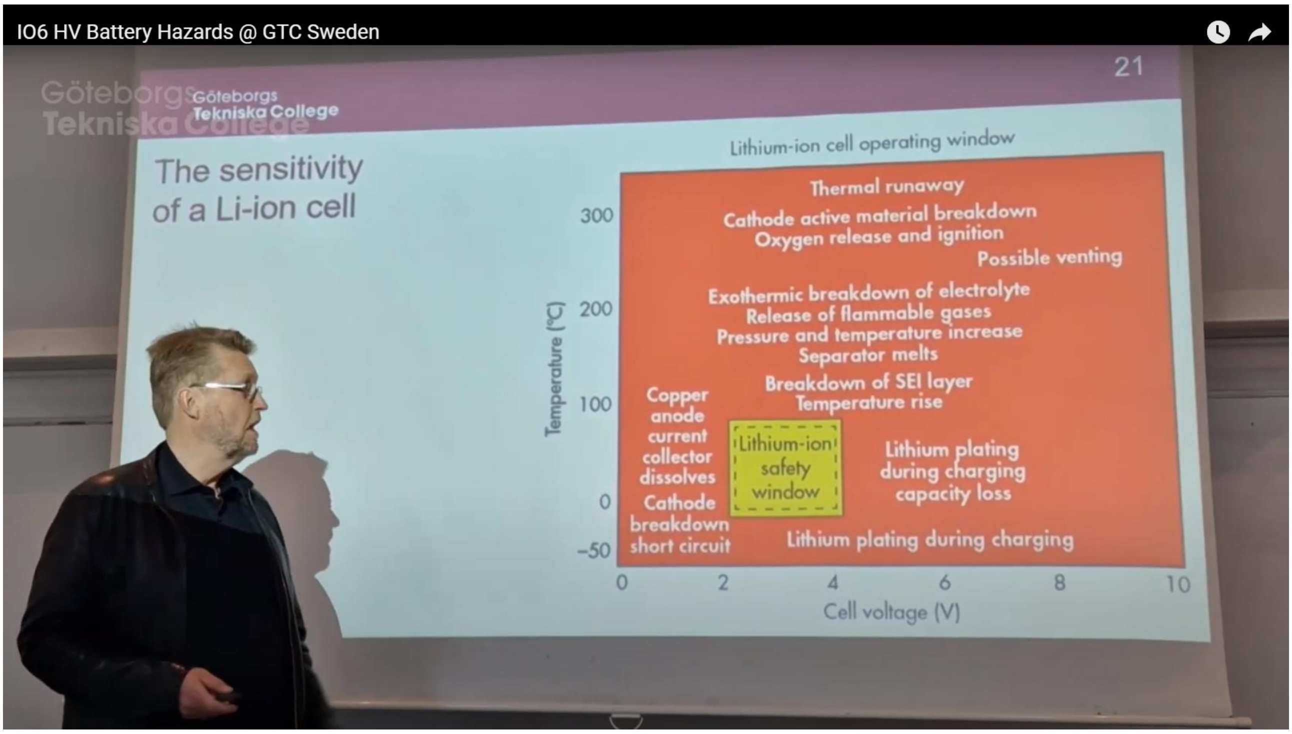
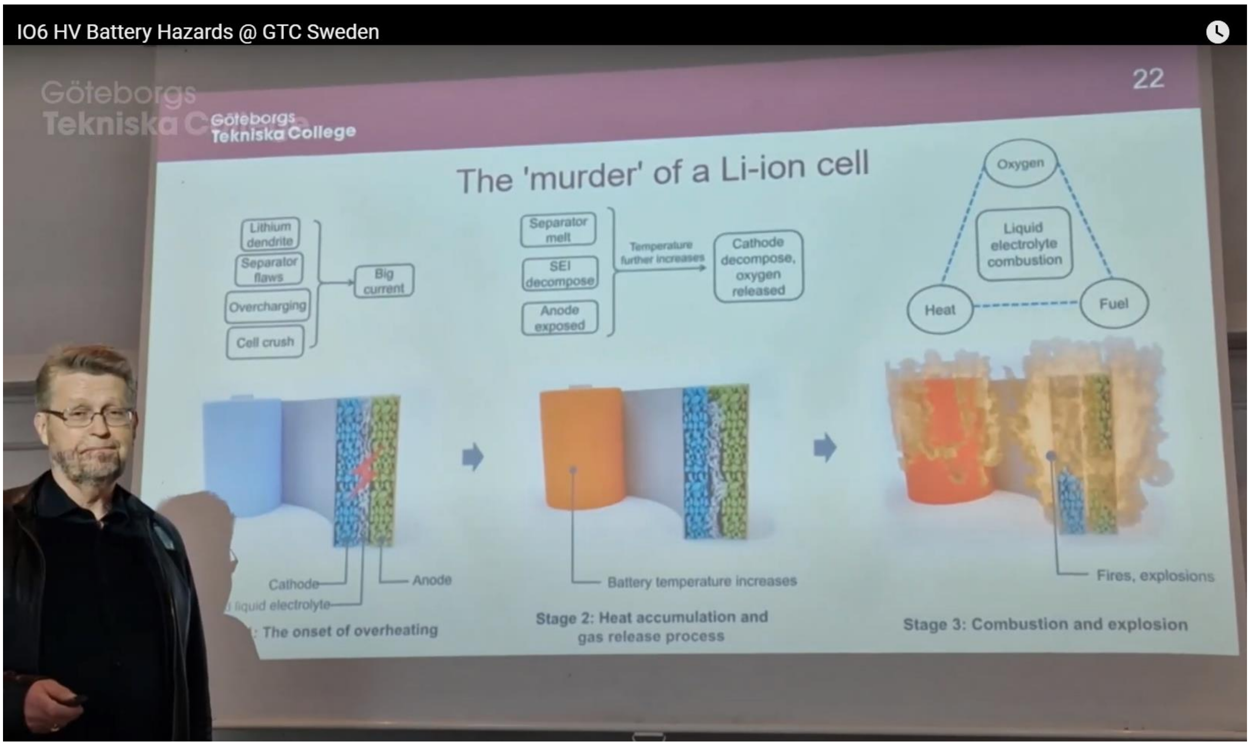


3) The sensitivity of a Li-Ion battery cell and its safety window in terms of temperature and voltage



4) The “murder” of Li-Ion cell: voltage and temperature fluctuations as cause of damage and hazard



EVALUATION FORM		
Students’ Performance		
Students were engaged and interested	YES	Very interested despite the theoretically hard topic.
Students are able to apply theoretical knowledge to practical tasks	YES	More knowledge on battery systems and diagnostics is needed

tudents were able to perform task	NA	
Students are able to work autonomously	In part	More knowledge on battery systems and diagnostics is needed
Students were aware of safety procedures	YES	
Students were able to use diagnostic tools	In part	More knowledge on battery systems and diagnostics is needed

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	Achieved
Entry level knowledge and skills of the students	More knowledge on battery systems and diagnostics is needed
Equipment & Tools	Deeper knowledge of the dealers' software would be needed to operate effectively

Supervision & Tutoring	Effective
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	More knowledge on battery systems and diagnostics is needed
Missing skills for students:	Ability to apply work procedures
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ More corporate trainers appointed to VET teaching would be needed
Further examples of topic-related troubleshooting problems	
EQF level 3	-
EQF level 4	-
EQF level 5	-

Option 2 – International regulations on safe shipping of HV battery @ VAVM and Moller Auto, Lithuania

This program was designed and tested by the Lithuanian Team, composed by the VET provider **VAVM - Vilniaus Automechanikos ir Verslo Mokykla** and **Moller Auto Lietuva**, Volkswagen & Audi national dealer, both based in Vilnius

At VAVM - Vilniaus Automechanikos ir Verslo Mokykla there are two main specializations running on:

-Automotive Mechanic (EQF 4)

-Automotive Electric Equipment Repairer (EQF 4)

Courses do not currently provide a specialisation in HEVs/EVs or avionics circuits, yet work-based training also include maintenance and diagnostics operations on hybrid or electric vehicles. Training modules include contents, knowledge and skills suitable to become the starting point which further e-mobility training can be based upon. Such topics include the following modules:

-Engines technical maintenance

-Transmission technical maintenance

-Automobile electrical equipment repair

-Engines electrical equipment

-Transmission electrical equipment

-Automobile comfort and safety electrical equipment

Task: International regulations and safety precautions around the shipment of Li-Ion Batteries

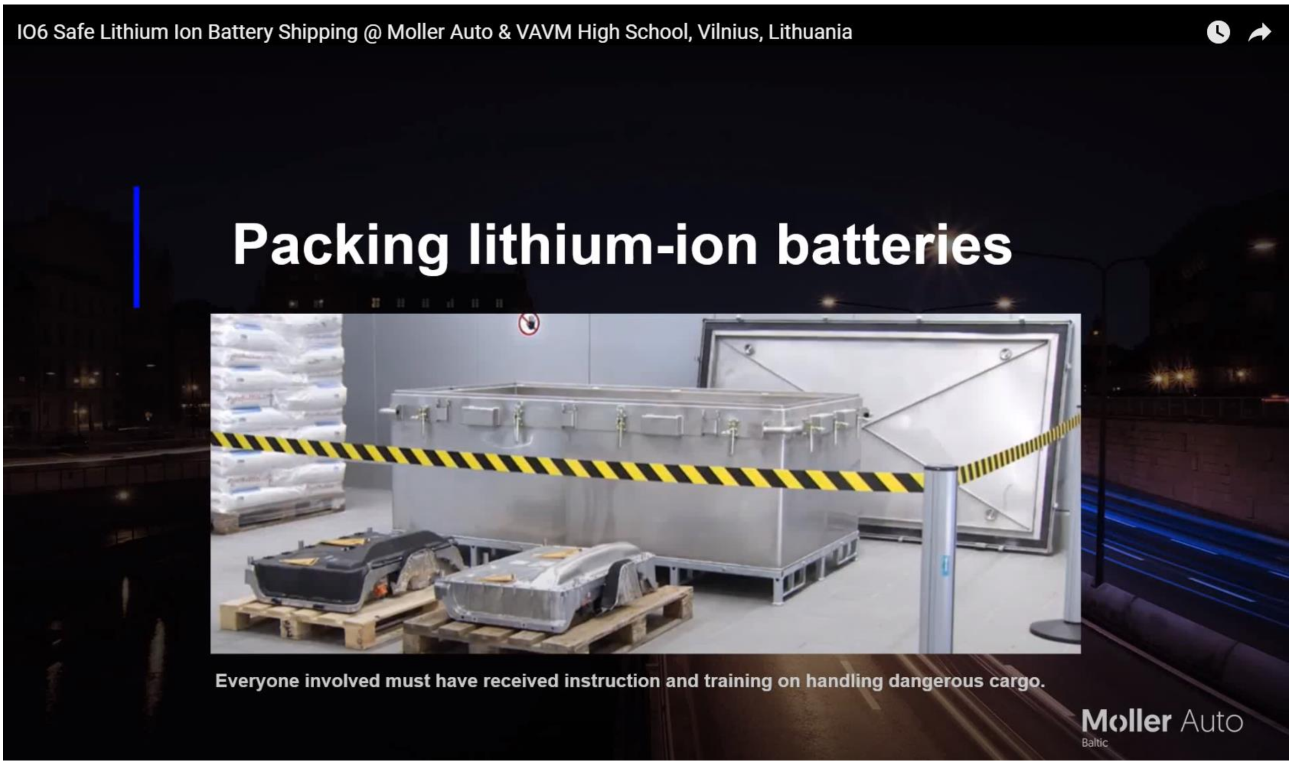
This is a totally frontal lesson. It implies developing knowledge about the physical and chemical hazards causing damage to battery as well as health risks to human beings. On the other hand, it does not imply any practical skills or hands-on work. Given the fact that the program is totally theoretical, it is suitable even for EQF 3 learners without any work-safety qualification about electrical works.

DESIGN FORM	
Task	***International regulations and safety precautions around the shipment of Li-Ion Batteries***
Learning Objectives	Developing knowledge about how to pack and prepare for shipment different size Lithium-ion batteries
Entry Level Knowledge (Theoretical)	Basic Electrically instructed Person qualification
Hard Skills involved	Prerequisites - Lithium-ion batteries as a dangerous cargo; Roles in the transport process in accordance with ADR[2]; Handling lithium-ion batteries; Packing lithium-ion batteries
Soft Skills Involved	English language Obligations to report and documents
Activities & Procedure required at EQF level (forecast)	III Level
Equipment & Tools to be used	Specialized containers, packaging materials, heavy weight moving equipment
Other Professional Roles involved	BEV/HEV Specialist/Supervisor Service advisor
Supervision & Tutoring Activities	Overview of processes during lesson

[2] ADR is the European Agreement concerning the International Carriage of Dangerous Goods by Road, dating back to a UN conference in 1957. The original French name for the 1957 Treaty was *"**A**ccord européen relatif au transport international des marchandises **D**angereuses par **R**oute".*

Expected Results / Solution	Students will learn how to prepare, pack and ship HV batteries.

The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:



Index of main contents:

-Every operator involved in the process of preparing a battery for shipping or of receiving and unpacking a battery, must receive instructions and training about how to handle hazardous cargo.

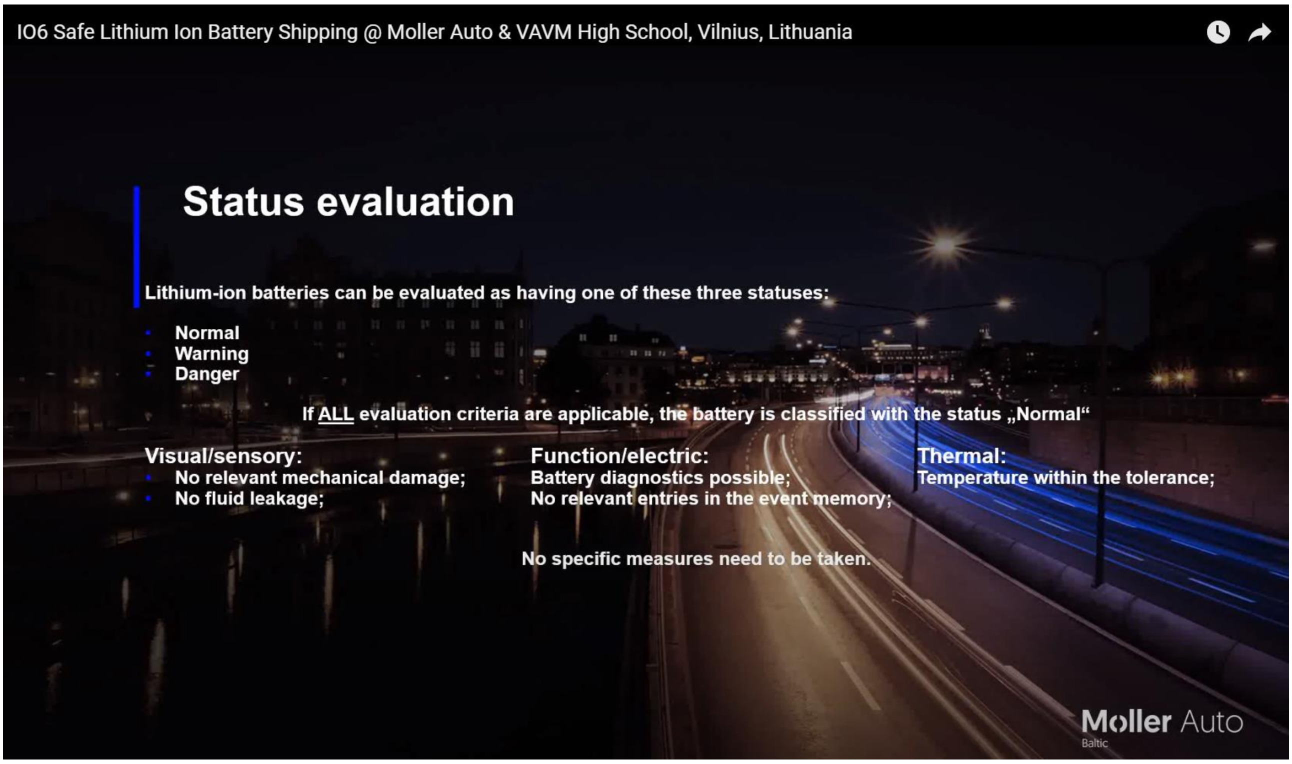
-Potential dangers of Li-Ion batteries: chemical dangers (leakage of toxic components such as electrolyte liquid, risk of chemical pneumonia, blood poisoning, skin burn or material corrosion) and risk of fire and of explosions.

-Health & safety risks involved with electrical voltage close to or above 60V.

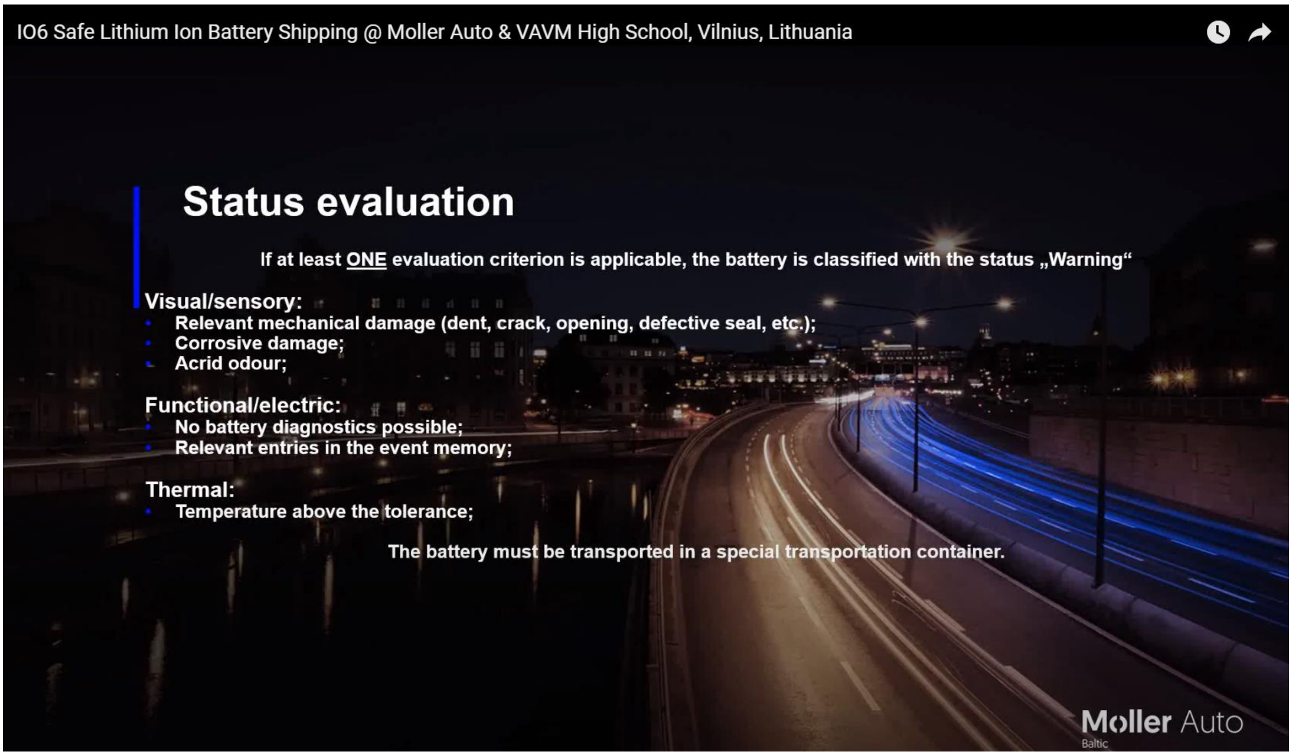
-Difference between battery cells, battery modules and battery packs. Classification of items for shipping according to the ADR Treaty about the transportation of hazardous goods.

-Criteria for the evaluation of the state of health of the batteries: conditions range from “normal” to “warning” to “danger” level.

Visual inspection (no evident cracks, mechanical damage or fluid leakage), electrical function (battery diagnostics is possible) and thermal conditions (temperature) are responsible to determine the status of the battery:

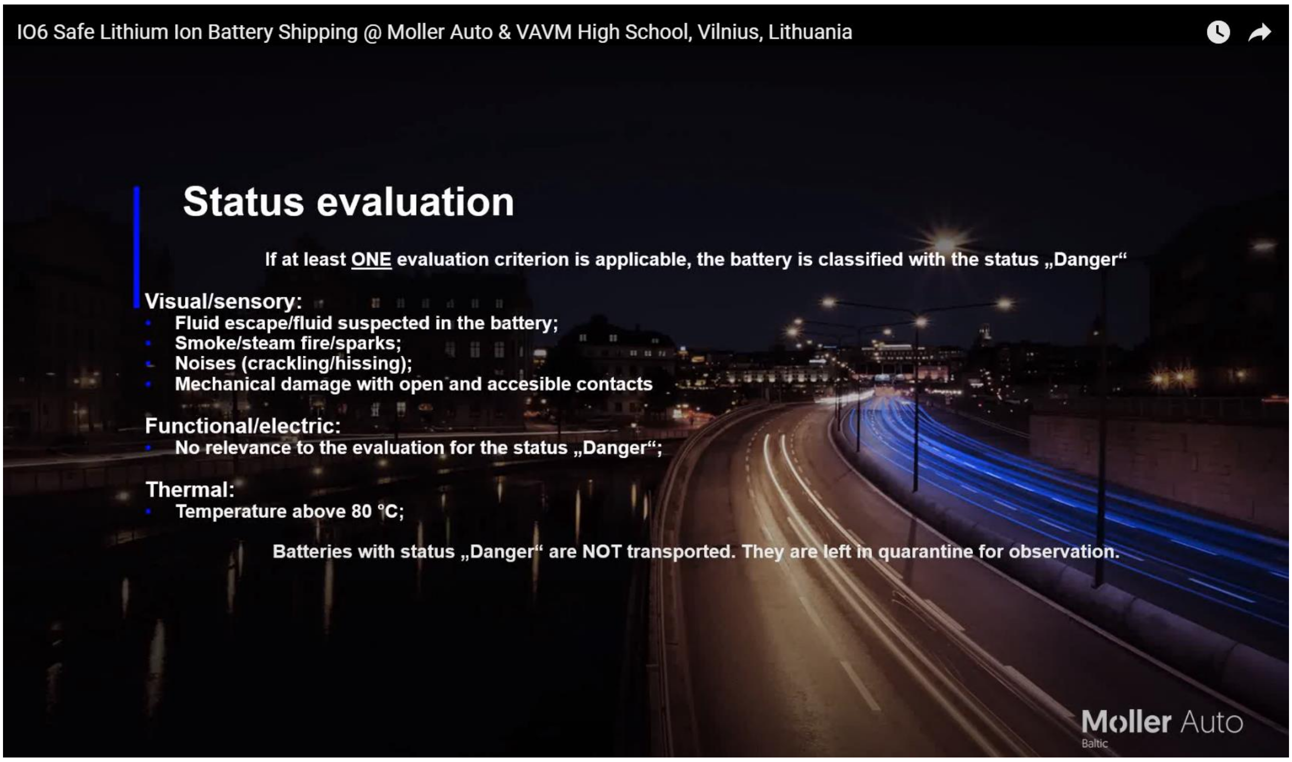


If all evaluation criteria are met, the battery is in normal status and can be prepared for shipping.



If any of those three criteria is not met, the battery is in “warning” status. It has to be put in quarantine until shipping. After the quarantine period is over, shipment is allowed under special packing conditions.

On the other hand, the “danger” status is declared when either the temperature of the battery pack is above 80 C°, or there are cracking or hissing noises from the battery case, or fluid leakage is present, or smoke / fumes are present, or no measurement about electrical activity is possible. No battery is shipped in such “danger” conditions: it is left in quarantine for observation, possibly immersed in water to reduce temperature.



-For batteries with normal status, the original case is used for packing and shipping, provided that all contacts are protected against external short circuits, while special insulating metal containers are used to ship batteries with “warning” status.

-The containers to pack the batteries for shipping must be filled with glass granulate beneath and above the battery itself. Glass granulates are small glass balls, so it’s a mineral and iron-free material. For this reason, it is great for multipurpose – it protects all wires and contacts from touching each other from potential short circuits. It is also fire proof.

-The battery case must show the sign “hazardous goods – class 9” and the UN3480 code, representing lithium-ion batteries.

-In case the battery is in the “warning” status, the container must also bear the sign “warning: damaged lithium-ion battery”.

EVALUATION FORM		
Students' Performance		
Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	NA	
Students were able to perform task	NA	
Students were able to work autonomously	In part	*Guidance from VET trainers was needed*
Students were aware of safety procedures	YES	*Instructed people only*
Students were able to use diagnostic tools	In part	*Guidance from VET trainers was needed*

VET Teachers & Trainers	
Learning Outcomes	Achieved

Expected results	Partly achieved The topic needs more attention and students need to take seriously the procedures about packing used batteries as well as safety issues
Entry level knowledge and skills of the students	The general level was adequate.
Equipment & Tools	When equipment is appropriate, it is used in the correct way. Nonetheless, it is not easy to find suitable containers and insulation materials to ship used batteries, especially at VET level.
Supervision & Tutoring Potential improvements	Effective Students should be observed and evaluated by two teachers at the same time to make sure assessment is objective.
Business Technicians	
Extent of transferability of the developed skills to the job market	Partial A full preparation about all the necessary requirements, procedures and materials is necessary to access the job market
Suggestion for further development	

Missing skills for students	Ability to put work procedures in practice; Deeper knowledge about HV components.
Development of teachers' role	More connections with the corporate sector More business technicians appointed to VET teaching and training.
Further examples of topic-related troubleshooting problems	
EQF level 3	-
EQF level 4	-
EQF level 5	-

Option 3 –Electric vehicle fire rescue at ROC Midden Nederland

The training program was designed & tested by ROC Midden Nederland (VET provider) and Innovam (company), and is targeting VET students attending the following courses:

- First Car Technician (EQF 3)
- First Truck Technician (EQF 3)
- Technical Specialist Car Technology (EQF 4)
- Technical Specialist Truck Technology (EQF 4)

All of them already include, in the regular training paths, teaching contents about the following units:

- Hybrid and electrical drivetrain
- Electric engines
- NEN9140 (EU regulation about electrical works)
- Charging Systems
- Inverter/Converter Battery Management

This program simulates a danger situation where smoke and fumes are released by an electric or hybrid vehicle. Despite the rescue process involves the fire brigades performing the actual operations, only learners with former training and instructions about electrical risks, explosion risks and chemical hazards should be allowed to participate in this session. On top of this, only trainees holding certified electrical training certificate should be allowed to secure the vehicle or handling water pumps for cooling. For further details about electrical safety when dealing with e-vehicles, ROC Midden Nederland and Innovam do include such topics in a short one-day modular course for students and workers called "Safe working on e-vehicles basics" (see Output 1), as well as in de-energization of HV battery described in Output 2 and Output 3 of the IG2 project.

DESIGN FORM	
Task	**E-vehicle rescue procedures in fire event**
Learning Objectives	Being aware of the dangers of an EV after an accident Being able to use the emergency response guide Being able to use personal protective equipment

Entry Level Knowledge (Theoretical)	Safety operations procedures involving EV/HEV
Hard Skills involved	Knowing how wear individual protection equipment (fire safe suit, helmet, face shield, breathing mask, insulating gloves, safety shoes); Being able to use thermal imaging camera
Soft Skills Involved	Cooperating with other rescue services, in particular the fire brigade. Working under time pressure and dangerous situations
Activities & Procedure required at EQF level (forecast)	Following the procedures in the emergency rescue guide at EQF level 3
Equipment & Tools to be used	Camera and/or drone to capture images, shower tools to water the affected e-vehicle, tablet with fire brigade rescue guide, individual protective materials.
Other Professional Roles involved	Supervisor, teacher, potential fireworker…
Supervision & Tutoring Activities	Teacher and/or fire brigade commander supervises students
Expected Results / Solution	EV can be safely transported to the mechanical workshop for assistance and repair

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:

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Topics/procedure:

1- As soon as a suspected emergency situation about an EV/HEV arises (fumes and smokes from the vehicle), call the local/national emergency number or the fire brigade;
2- As soon as the rescue team arrives at the premises, briefly inform the commander or person in charge about what happened;
3- The fire workers will wear breathing support to protect themselves from smoke and toxic chemical danger;
4- Special shower tools will be placed under and around the car to cool the affected battery down with water;
5- If cooling down is successful and no more smoke is released by the car, the vehicle is safe to be transported to the car repair workshop;
6- For severe battery heating or damage, it might be necessary to submerge the vehicle in water. In such cases the vehicle will be lifted up with a crane and transported to a special tank filled with water to complete the colling process until the vehicle is safe.

EVALUATION FORM

Students' Performance		
Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	YES	*Remarks: the entire operation was led and performed by the fire brigade.*
Students were able to perform tasks	NO	
Students were able to work autonomously	NO	
Students were aware of safety procedures	YES	
Students were able to use diagnostic tools	NA	

VET Teachers & Trainers	
Learning Outcomes	Partly achieved The fire brigade covered only the practical rescue demonstration procedure but did not cover all the issues related to emergency situations affecting EV/HEV
Expected results	Partly achieved

	Not all information related to rescue safety of the vehicle was available
Entry level knowledge and skills of the students	Adequate level to engage in the experimentation thanks to self-study beforehand
Equipment & Tools	Used properly
Supervision & Tutoring	Effective *Remarks: Students were very eager to learn and listened carefully to the tips of the trainer. At this point in this training no points for improvement to indicate*
Business Technicians	
Extent of transferability of the developed skills to the job market	Partly – some contents are very specific for the fire brigade
Suggestion for further development	More theoretical training about dangers and hazards related to explosions and chemical risks
Missing skills for students:	
Development of teachers' role:	✓ Wider access to teachers' training or update
Further examples of topic-related troubleshooting problems	

EQF level 3	-
EQF level 4	More knowledge and skills needed on how to repair vehicles involved in accidents, brought in the workshop by rescuers.
EQF level 5	More knowledge and skills needed on how to repair vehicles involved in accidents, brought in the workshop by rescuers.

Option 4 –After sales assistance at IIS A. Ferrari, Maranello, Italy (EQF 3-4 levels)

Such tasks were performed by students attending the technical and vocational courses (EQF 4) at IIS "A. Ferrari" in Maranello (Modena, Italy).

Based on the learning objectives of the project - getting students familiar with the electric and hybrid vehicles, batteries and engines, the following study courses were identified as most suitable to run IG2 project's experimentation:

- Maintenance and Technical Assistance (EQF 4)
- Technician for the Construction of Transportation Means - Road Vehicles (EQF 4)

At such a level students attend mandatory work safety courses - both general safety recommendation at work and specific mechanic and electrical risk training, but, given their young age, they are not usually trained as EiP (electrically instructed person) and they cannot work with high voltage batteries or circuits.

Students at such level are trained to perform maintenance operations on the mechanical part of the vehicles, but they are not allowed to install or repair any electrical circuit, including of course HV batteries.

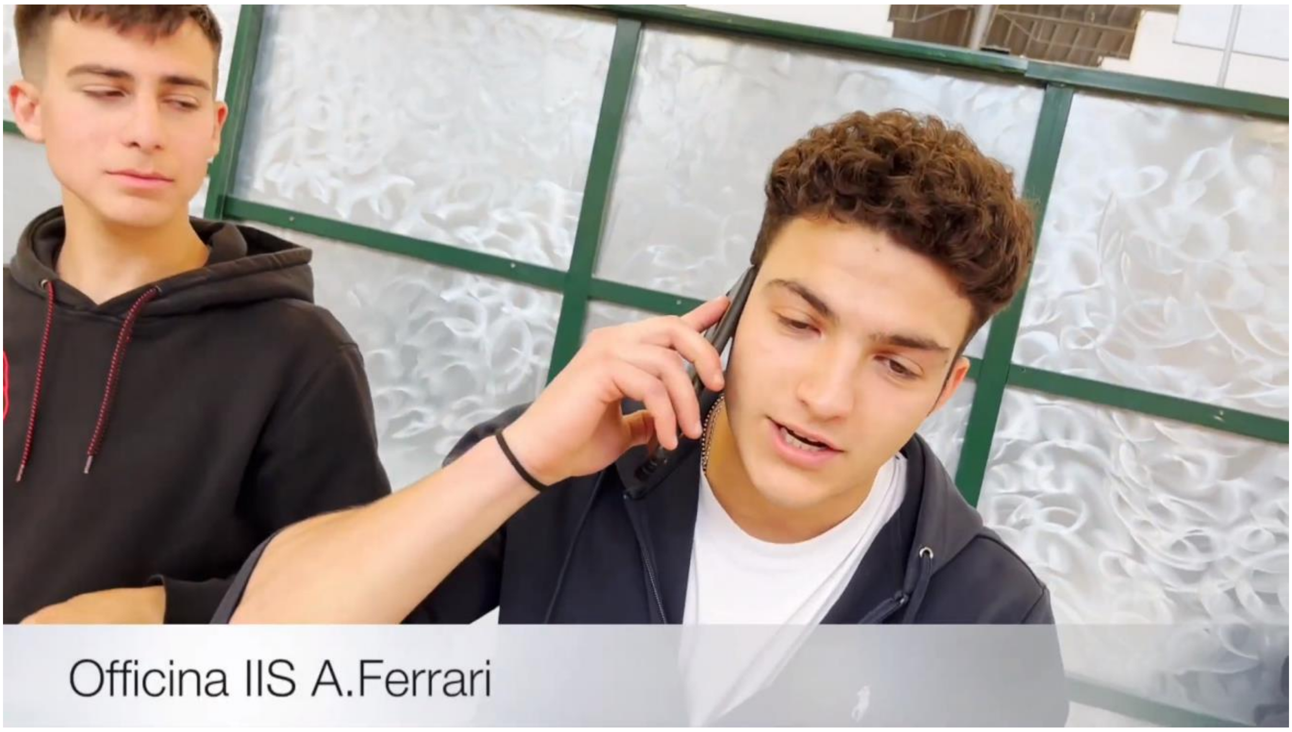
At Ferrari VET school students learned first about the structure and working mechanism of the electrical part of motor engines (see Output 2), then about the maintenance through electronic diagnostics thanks to the OBD software (Onboard Diagnostic Tool, see Output 3).

At this point students were involved in an after sales simulation, performing a negotiation between a customer experiencing a problem with his e-vehicle and the mechanical workshop, providing assistance and options about how to deal with problems affecting an HV battery.

DESIGN FORM	
Task	***After-Sales assistance to customers holding an electric or hybrid car***
Learning Objectives	Being able to offer assistance to customers experiencing problems with EV/HEV; Knowledge of potential failures of HV batteries and their causes; Being able to provide instructions and directions to customers to prevent hazards for human life and further damages to the vehicle.

Entry Level Knowledge (Theoretical)	Basic car mechanics Electrical circuits of vehicles Features and working mechanism of HV batteries
Hard Skills involved	Able to operate with an OBD (Onboard diagnostic tool)
Soft Skills Involved	Able to read and understand procedures in workshop manuals and diagnostic tools. English language Negotiation and communication skills
Activities & Procedure required at EQF level (forecast)	EQF 3-4 Level
Equipment & Tools to be used	OBD dealership software.
Other Professional Roles involved	VET trainer or workshop manager
Supervision & Tutoring Activities	Theoretical explanation of HV battery systems
Expected Results / Solution	Students will be able to understand how to deal with customers in emergency situations and to give them proper directions. Students will also develop sills in understanding which problems and their level of complexity, asking relevant questions to customers to support their own diagnostic hypothesis, and to make the customer happy after looking for the garage assistance.

Testing with relevant work procedures is portrayed in the instructional video available on IG2 project's official YouTube Channel @innovationgarageerasmuspro1264:



The video portrays two main customer care situations:

-in the first one, a customer experience a failure while driving an EV/HEV. The driver calls the car workshop for assistance and the operator warns him about not to touch any orange cable inside the car hood, as this is the high voltage system which is dangerous for human life. The operator will send a tow truck to rescue the car which will be taken care of in the workshop.

-In the second one, a customer complains about the low performances of the battery of his EV/HEV. After talking with the garage operator, they find out the battery already completed 1500 recharge cycle: at this point the battery has a physiological decrease in its performances. The operator offers two options to the customer: either replacing the battery with a new one, or choosing a new vehicle with a lighter battery pack and a higher performance potential.

EVALUATION FORM		
Students' performance		
Students were engaged and interested	YES	Students were assigned the task of making hypothesis of

		typical HV battery failures or emergency situations to simulate a phone call between the customer and the car workshop
Students were able to apply theoretical knowledge to practical tasks	NA	Theoretical training only
Students were able to perform tasks	YES	
Students were able to work autonomously	YES	With some guidance from the teachers about the correct way of communicating technical details to the customer
Students were able to find faults	NA	Theoretical training only
Students were able to identify safety procedures	YES	
Students were able to use diagnostic tool	In part	With some guidance from the teachers about the dealers' OBD tools (onboard diagnostic tools)

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	Achieved

Entry level knowledge and skills of the students	Adequate level of self study
Equipment & Tools	Adequate level of awareness
Supervision & Tutoring	Effective
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	Practice on finding faults in HV systems using OBD software (onboard diagnostic tool)
Missing skills for students:	Knowledge of organizational / business roles
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ Deeper or up-to-date knowledge of software or diagnostic tools
Further examples of topic-related troubleshooting problems	
EQF level 3	None

EQF level 4	More knowledge and skills needed on how to repair vehicles involved in accidents, brought in the workshop by rescuers.
EQF level 5	More knowledge and skills needed on how to repair vehicles involved in accidents, brought in the workshop by rescuers.

Option 5 – After sales assistance @ ITS MAKER Academy, Italy

Such a program was run by the EQF 5 level courses within the Fondazione ITS Maker, based in Bologna, training Higher Technicians in advanced technology, mechatronics and automotive fields.

Within IG2 project implementation, there are namely two courses with e-mobility related contents:

- Higher Technician in Hybrid, Electric and Endothermic Engines (EQF 5)
- Higher Technician in Electric & Connected Car and Assisted Driving (EQF 5)

Since both profiles envisage high specialisation standards, attainable with a tertiary education course after the general upper secondary certificate (EQF 4), the current IO5 program is only targeting VET learners with prior knowledge and skills about:

- Electrical schemes of vehicle circuits
- Electrical and electronic technologies and applications
- Installation and maintenance technologies and techniques

The IO6 task run by the Fondazione ITS Maker course in hybrid, electric and endothermic engines is about assisting a customer who is reporting a problem in the front camera of his/her electric FIAT 500 vehicle. The front camera is part of the ADAS systems explained in Output 4 and Output 5.

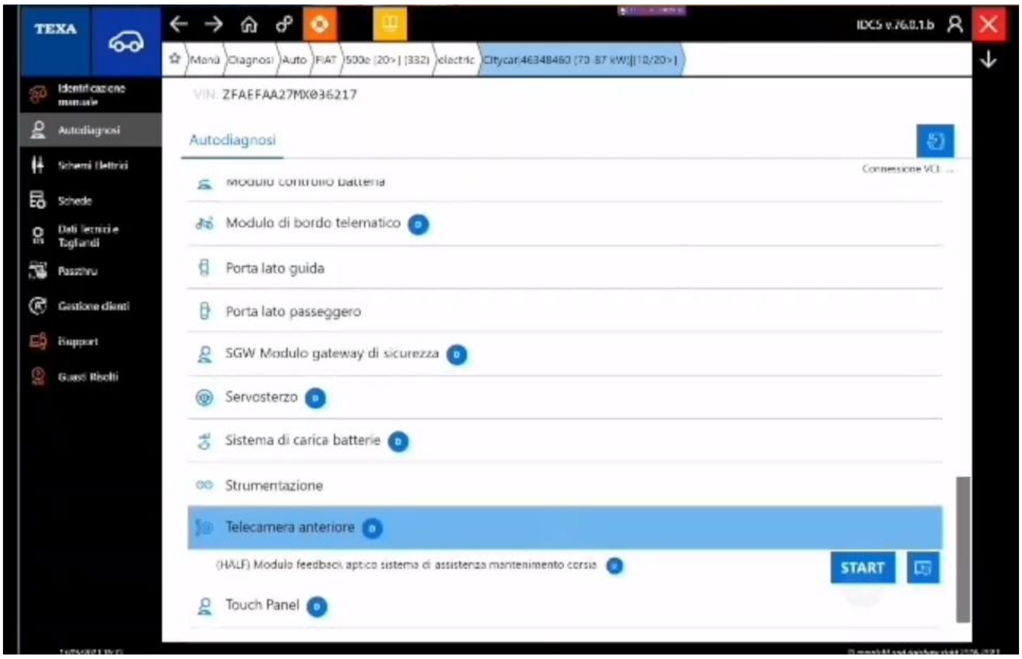
DESIGN FORM	
Task	***Replacing the front camera of an EV through the OBD software***
Learning Objectives	Knowledge of the main electrical and electronic circuits of vehicles in order to carry out correct maintenance in the event of faults.

Entry Level Knowledge (Theoretical)	Reading an electrical diagram, knowledge of laboratory diagrams and basic electronics
Hard Skills involved	Holding a diploma/qualification as well as a minimum of internship experience in the automotive sector
Soft Skills Involved	Complying with safety regulations in the workplace, especially in case of electrical hazards.
Activities & Procedures required at EQF level (forecast)	Measuring and analysing electrical parts and repairing damaged and/or defective parts
Equipment & Tools to be used	Electrical measuring and diagnostic tools.
Other Professional Roles involved	Software programmers and hardware developers
Supervision & Tutoring Activities	Correct use of personal safety equipment and correct use of work tools.
Expected Results / Solution	Knowledge of the main electrical and electronic circuits of vehicles in order to carry out correct maintenance in the event of faults.

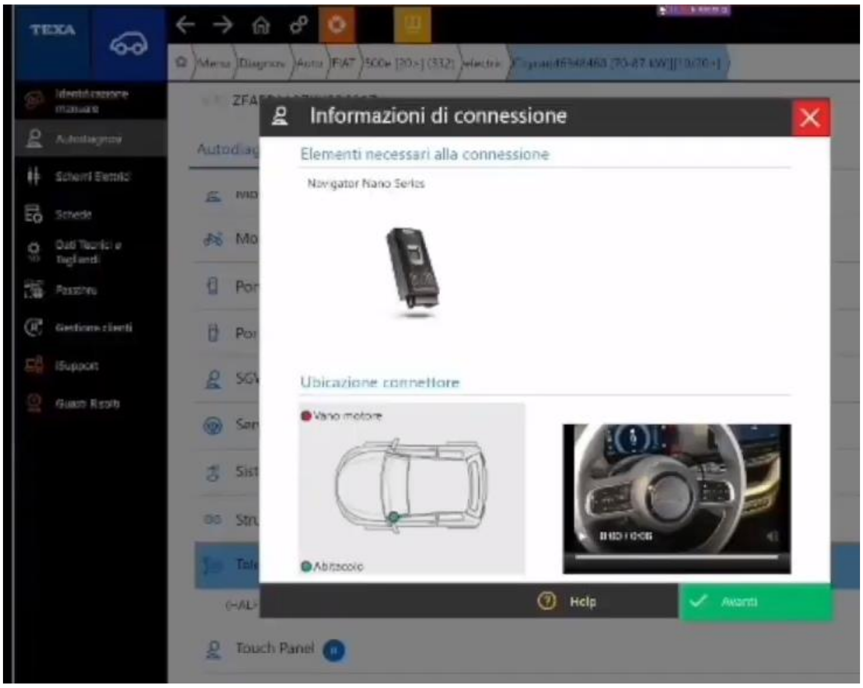
The testing was performed according to the technical procedure portrayed by the following video available on the IG2 Official YouTube Channel @innovationgarageerasmuspro1264:

Procedure:

1) After the vehicle is primed, yellow warning signs display there is anomaly in the system
2) The vehicle is then connected to the TEXA OBD software (onboard diagnostic tool) and a list of detected errors is displayed. The operator is thus able to find out there is a problem in the front camera.



3) Then the operator proceeds to replace the front camera with a new one. Before operating correctly, the new camera needs to be calibrated. The OBD tool offers information about which devices are necessary to calibrate the camera…



…as well as information about which calibration panel is suitable for the relevant kind of vehicle (FIAT 500 full electric).

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EVALUATION FORM		
Students' Performance		
Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	YES	
Students were able to perform task	YES	
Students were able to work autonomously	In part	*Guidance was needed from the trainer*
Students were able to find faults	In part	*Guidance was needed from the trainer*
Students were aware of safety procedures	YES	
Students were able to use diagnostic tools	In part	*Guidance was needed to correctly interpret the interfaces of the official dealer's diagnostic tools*

VET Teachers & Trainers	
Learning Outcomes	Achieved
Expected results	In part: it takes more practice to gain experience
Entry level knowledge and skills of the students	Partly adequate. Learners are still lacking practical skills
Equipment & Tools	Deeper knowledge of the dealers' software would be needed to operate effectively
Supervision & Tutoring	Effective
Business Technicians	
Extent of transferability of the developed skills to the job market	Complete
Suggestion for further development	-
Missing skills for students:	Ability to apply work procedures in the learning environment
Development of teachers' role:	✓ Wider access to teachers' training or update ✓ Deeper and up-to-date knowledge of dealers' software or diagnostic tools.

Further examples of topic-related troubleshooting problems	
EQF level 3	Applying safety procedures on voltage vehicles
EQF level 4	Diagnosing assisted driving systems and calibrate them
EQF level 5	Diagnosing anomalies on electric vehicles with ADAS

3. Collecting VET learners' feedback

As stated in the IO1 paper about designing a pilot Train-the-Trainers program about e-mobility, a relevant part of the program itself relies into collecting the learners' feedback about both their appreciation and their self-evaluation about the training experience.

Questions might vary according to the learning objectives of the experimentation and the EQF level of the VET provider, but on a general rule the following criteria should be met in order to administer feedback questionnaires to measure the impact of the training activities:

-forms should be collected anonymously to make sure respondents are free to express their sincere and honest feedback about the training program, either on a paper or digital format;

-questions might be multiple-choice or on a scale, but in any case some room for further comments or remarks should be left;

-the extent to which the training workplace helped students develop e-mobility skills should be assessed;

-the effectiveness of the mentoring or supervisory activities should be assessed;

-the extent to which prior knowledge and skills were allowed learners to make the most out of the training program should be assessed;

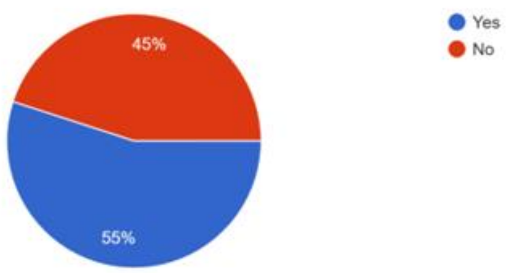
-the perception, on the learners' side, of actual development of e-mobility skills should be assessed;

-the extent to which learners think to be suitably prepared to transition to the job market.

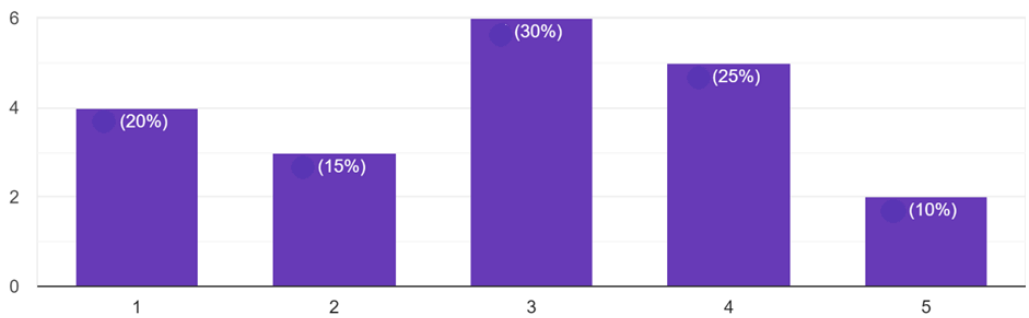
Examples of the collected feedback can be seen from the charts below, which report genderless aggregate data from all the countries and EQF levels involved.

Answers with scale from 1 to 5 mean that respondents were asked to rate the sentence in the questions with a score from 1 (absolutely not) to 5 (absolutely yes).

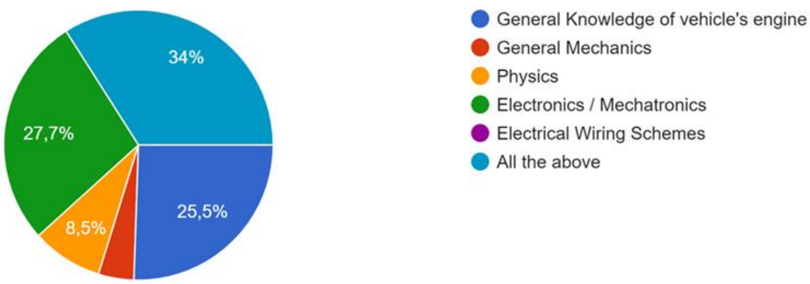
I already took classes in electro-mobility or HEV/BEV before participating in the project



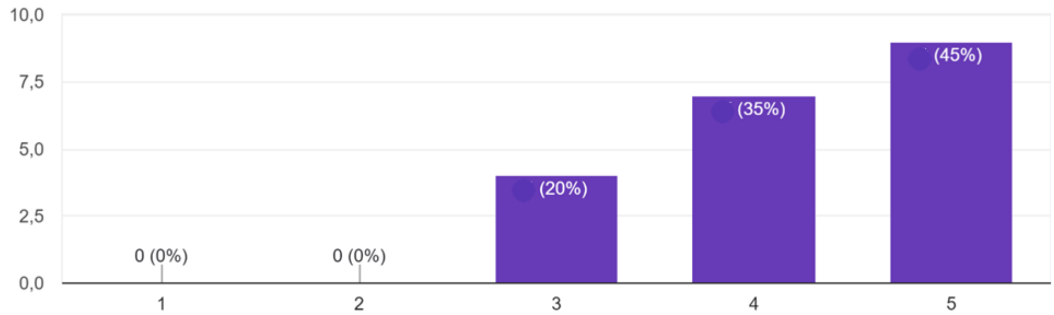
I think my previous knowledge & skills level was enough for me to take part in HEV/BEV testing



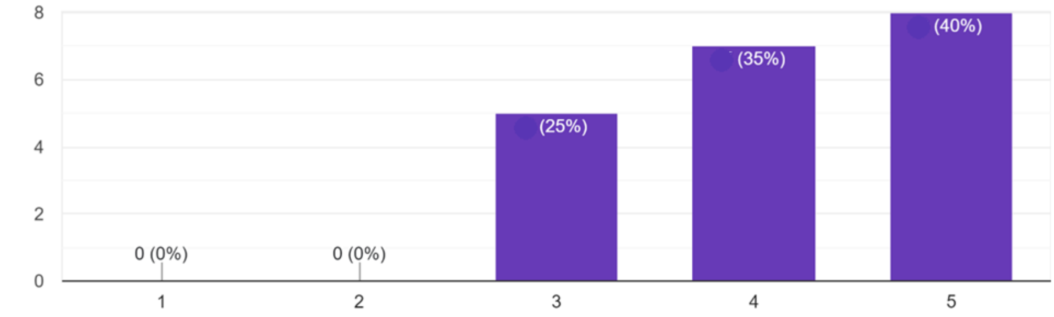
Which of the following was most helpful for you to make the most out of the HEV/BEV testing?



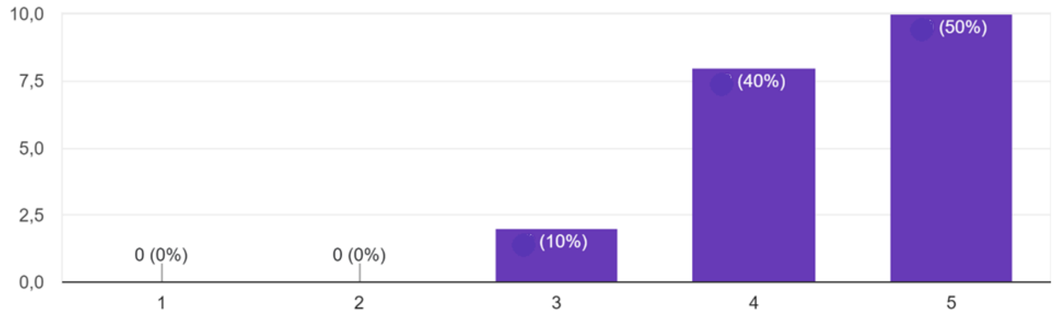
After the testing, I think I developed knowledge and skills about how to work safely on an HEV/BEV vehicle



After the testing, I think I developed knowledge and skills about how to secure an EV/HV after an accident



After the testing, I know which personal protection equipments I should wear and why



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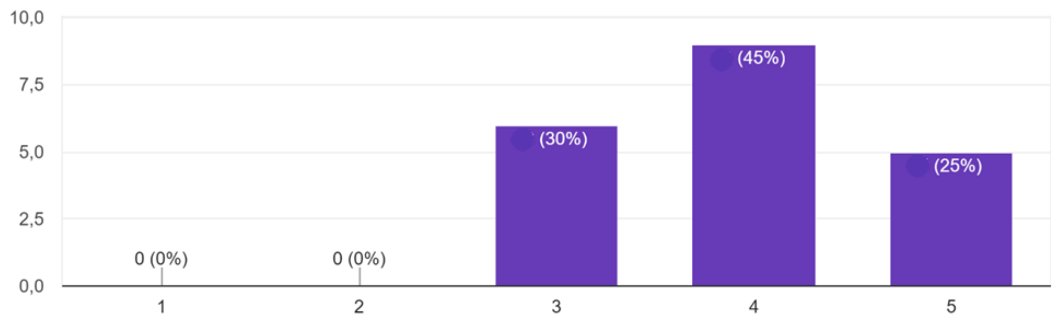
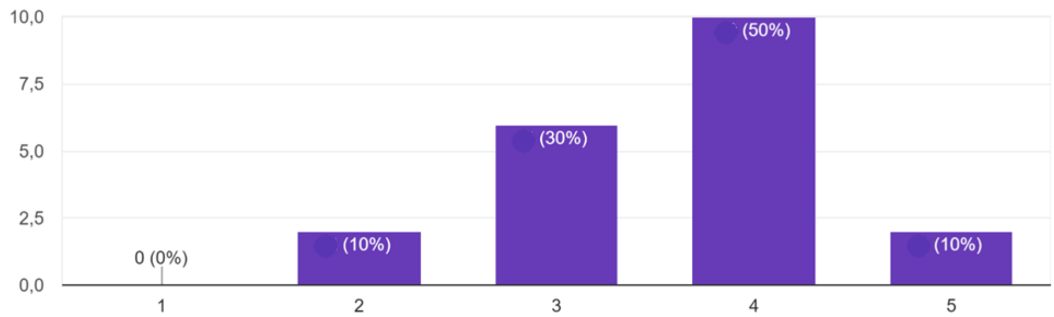
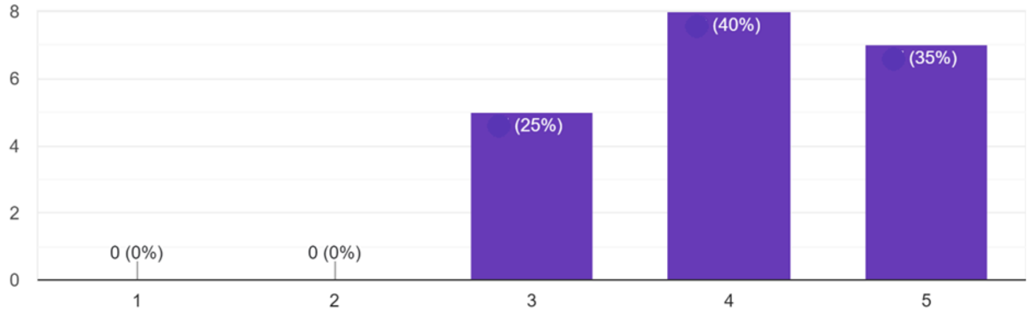
After the testing, I know the procedure to implement in case of emergency event or accident involving an EV/HEV vehicle



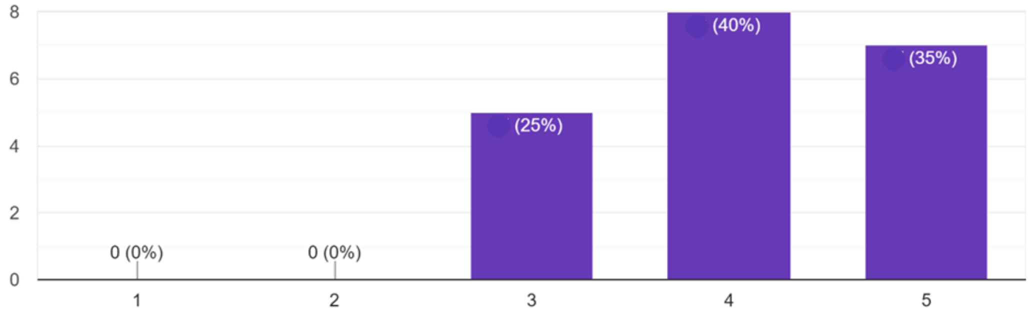
I developed knowledge about national / EU legislation about EV/HEV vehicles



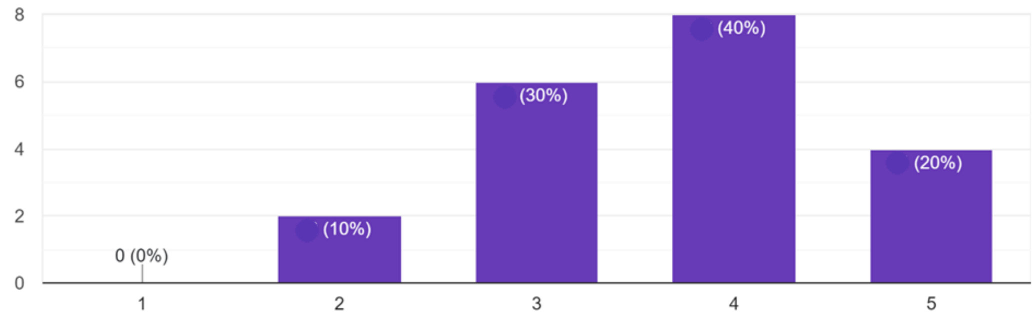
I developed knowledge and skills about EV/HEV battery



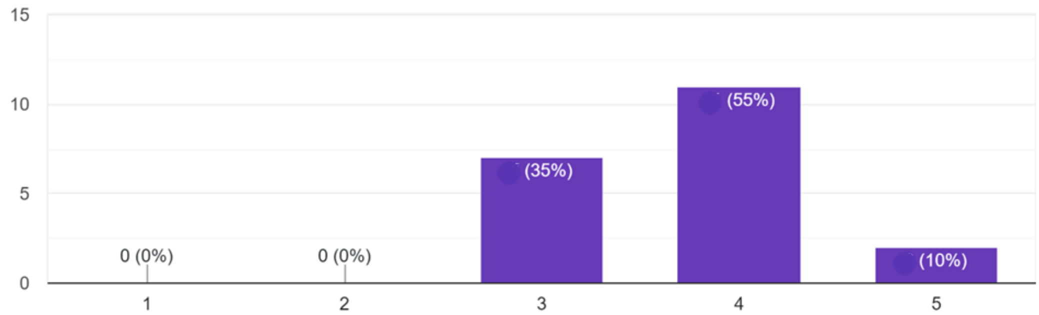
I developed knowledge and skills about EV/HEV battery



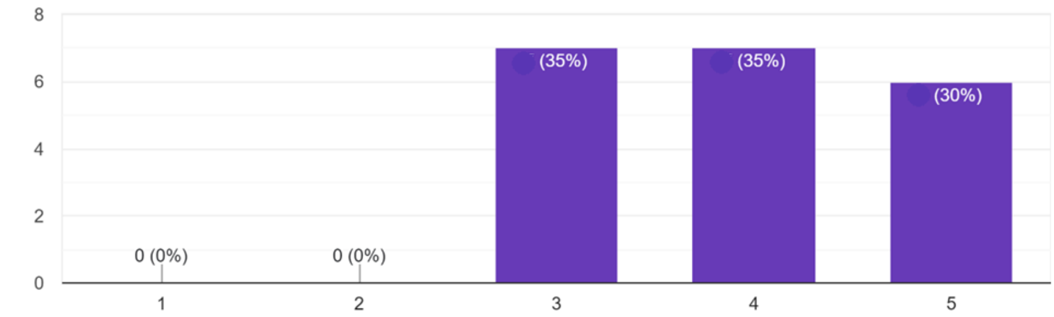
I think I can read electrical circuit wiring schemes



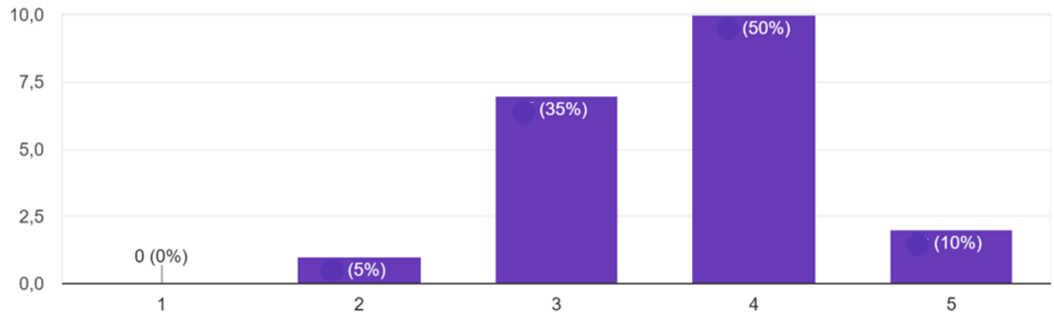
I developed knowledge and skills about how to perform failure diagnosis & repair in a EV/HEV system



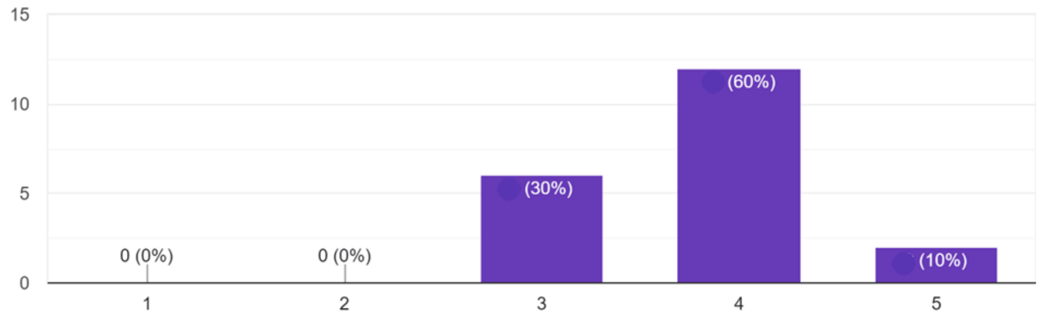
I think I was properly trained and supervised during the testing



I think I have better ideas about how a company workplace or a production plant or car workshops works



Thanks to the testing, I think I am better prepared for the automotive job market



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Conclusion: who is this paper for?

This paper represents the outcome of Intellectual Output 6 of “Innovation Garage of Garages” Erasmus+ project, aiming at developing green skills for the automotive sector at VET level.

The specific goal of such a paper is to provide guidelines for VET teachers and trainers willing to introduce hybrid or electric engines, high voltage and their components as a modular or integrated path within mechanics or automotive courses.

Multiple actors co-designing the training contents, the workplace layout and tools, as well as the organisational details of the didactic methodology (roles of trainers, facilitators, evaluation and assessment criteria, is the special footprint of the project. Since “Innovation Garage” is a worldwide methodology to introduce bottom-up multi-stakeholders innovation over the workplace premises, what this project is aiming at is renovating the way which “workshops” or “garage” training is usually performed.

So, this is just a proposal that needs to be customised with specific contents according to the target learners and the regular training courses within a VET organisation.

IO6 paper is suitable both for teachers and trainers at I-VET level (schools, training centres for young people or adults) from EQF levels 3-4, or even for H-VET at EQF 5 level (tertiary education other than university level). Nonetheless, e-mobility training can involve managers, technicians or trainers at company level - either at production houses, or repair workshops, or dealers, whenever workers need to develop or upgrade their skills about the management and maintenance of HV batteries, of HEV/EV vehicles and their components.