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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

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Training Program on HEV/EV maintenance

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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

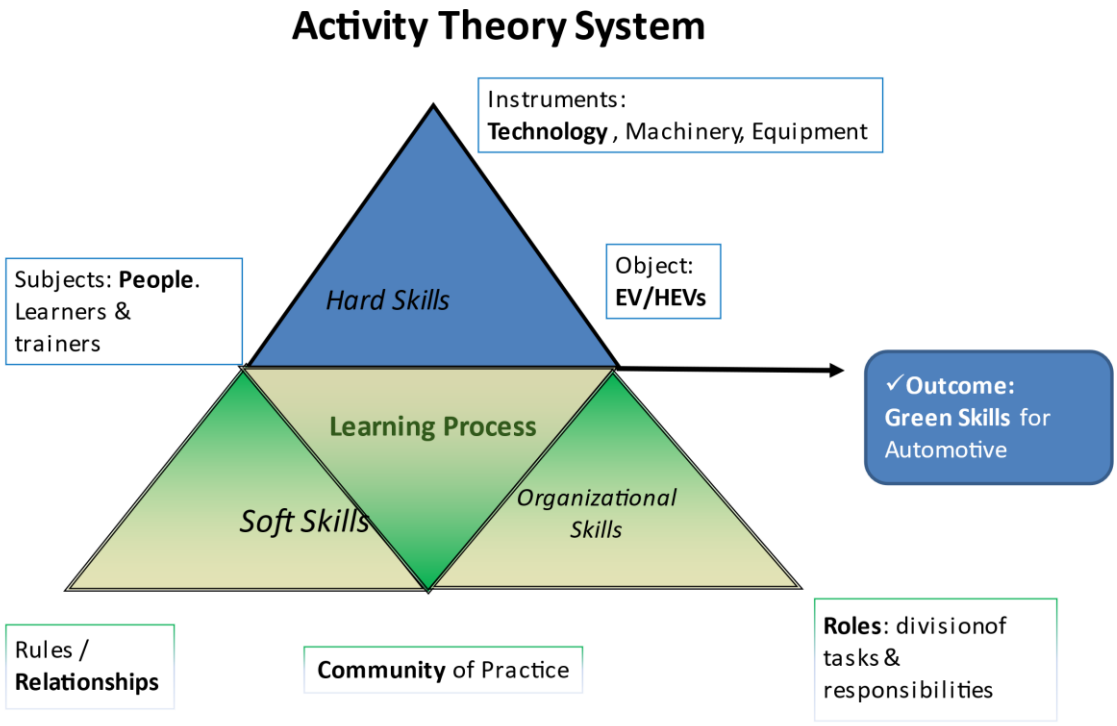
IO6: After-sales assistance & safety issues related to EVs/HEVs

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

- 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.

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:

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.

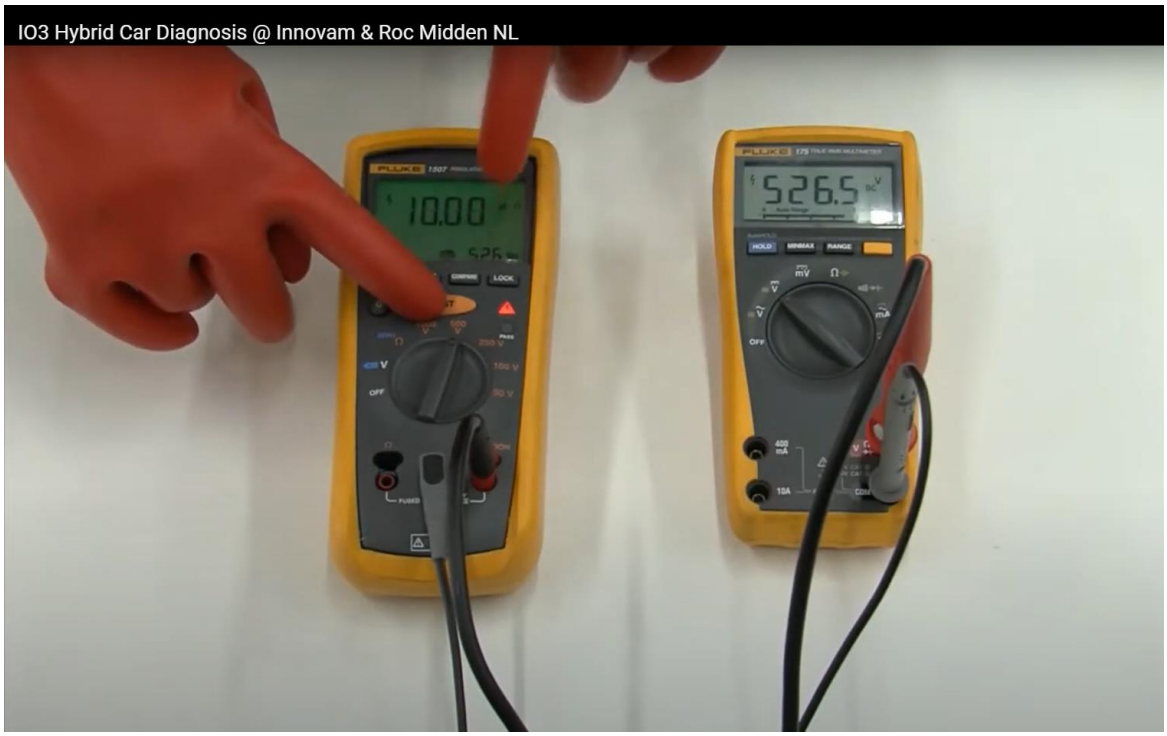
Access the measuring point for executing the “0 volt check” to verify that the HV system is dead.

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.

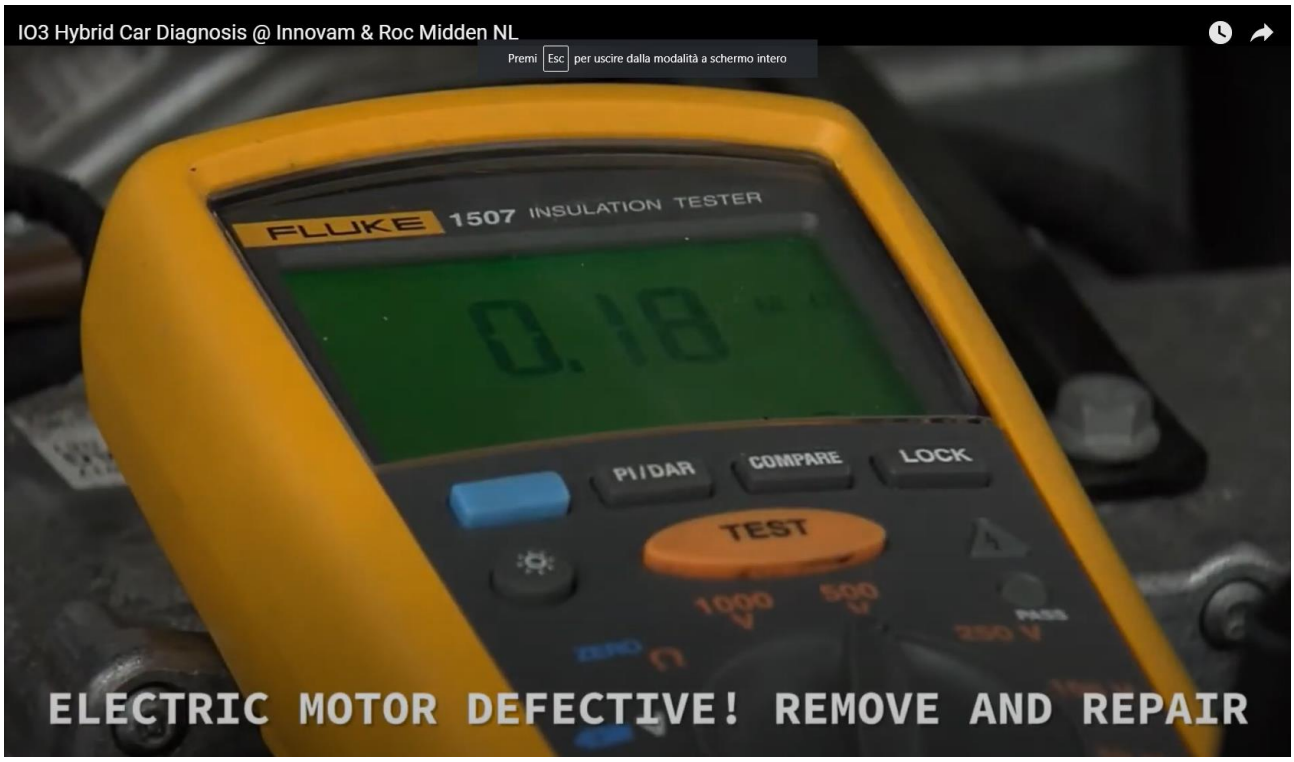
When the test button is pressed on the Megger, it reads 10.0 mega ohms on a scale of 526 1052 volts.

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

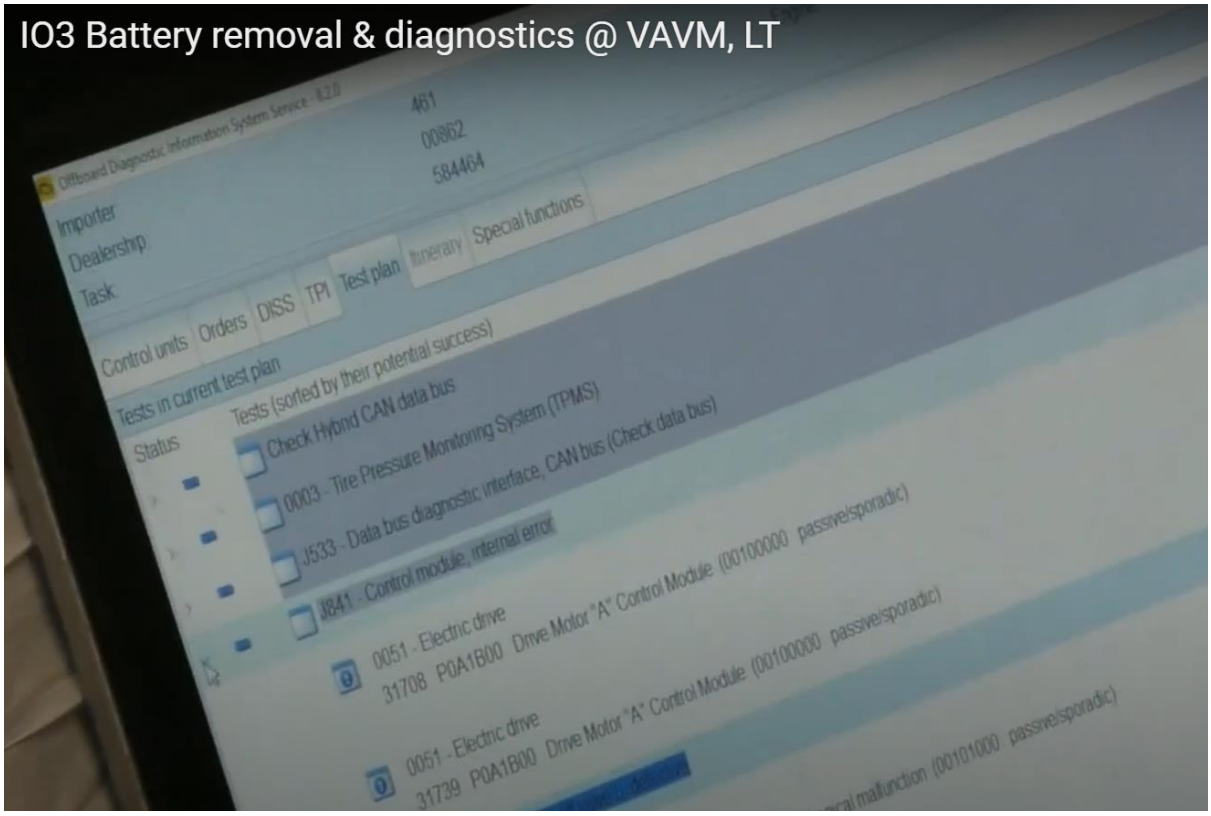
-Putting safety signs with the name of the operator working on the car

-Wearing rubber air tight gloves and protective glasses

-Removing and locking the service plug

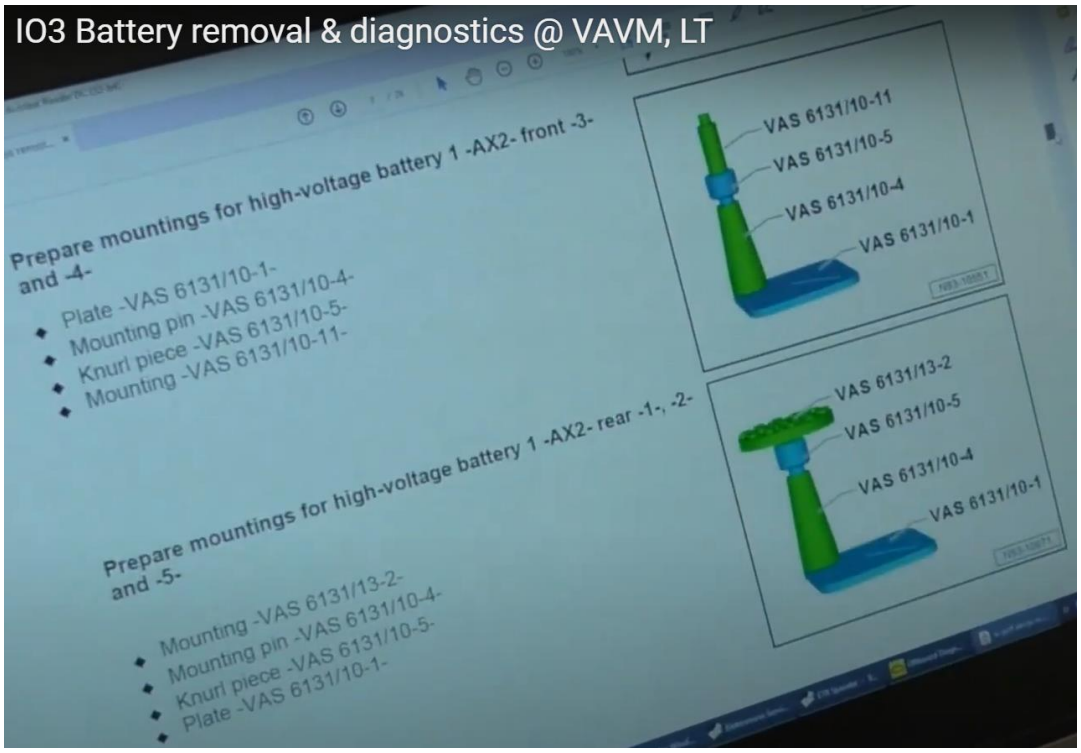
For a full recap of the safety procedure please check VAVM's Output 2 video about how to fix an EV/BEV.

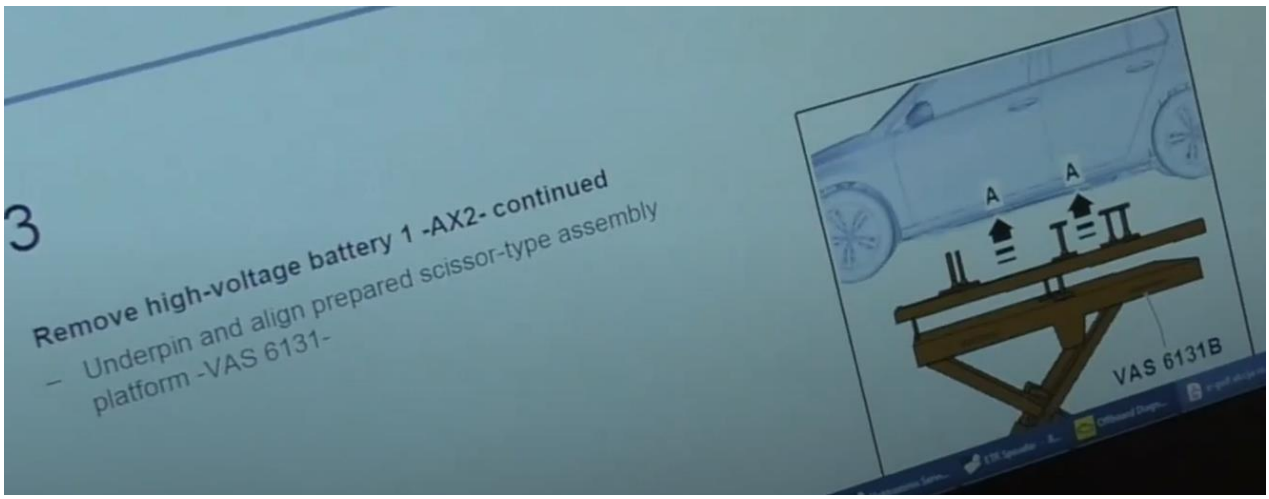
2 - Finding internal error through the OBD (Onboard diagnostic tool of the vehicle construction house): an error in the electric drive is detected.



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.



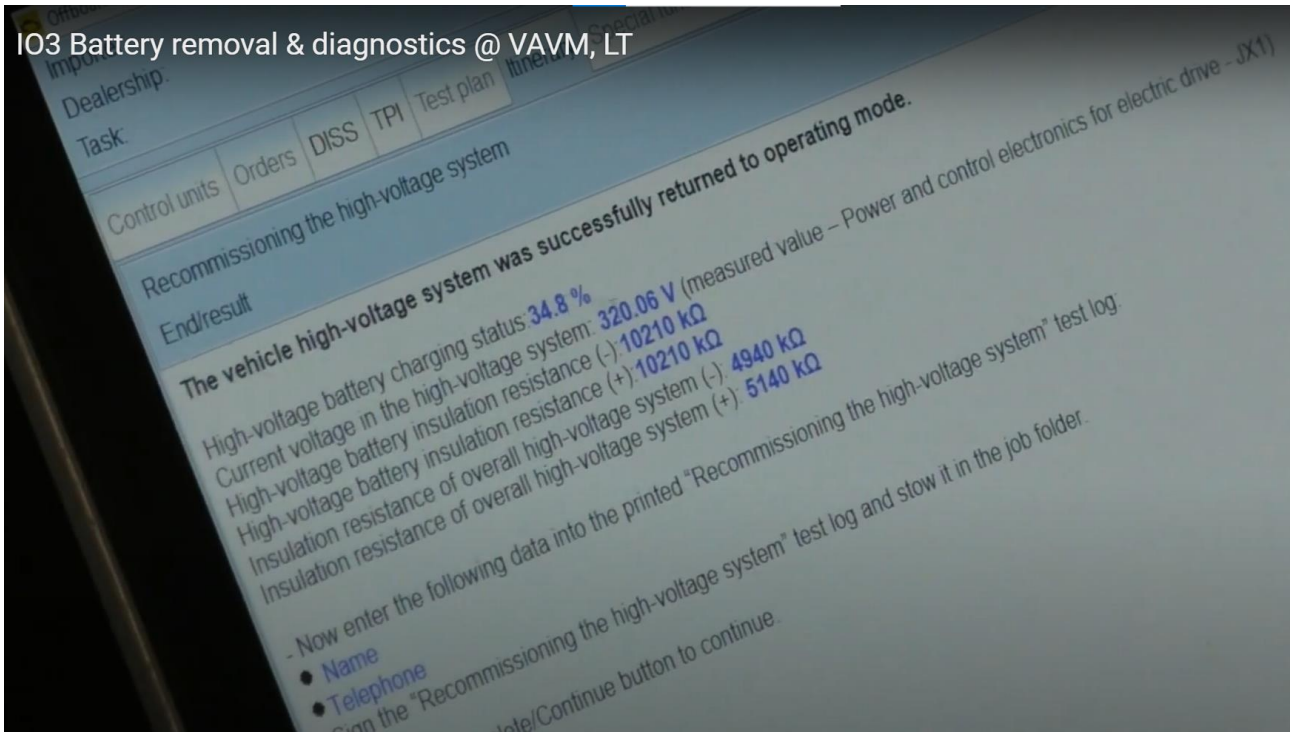


4- Now test the battery. The documentation of the construction house recommends an on-board voltage over 12V. This is to prevent damage on the HV system from low charge as well as the reduction of its life span.

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

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.

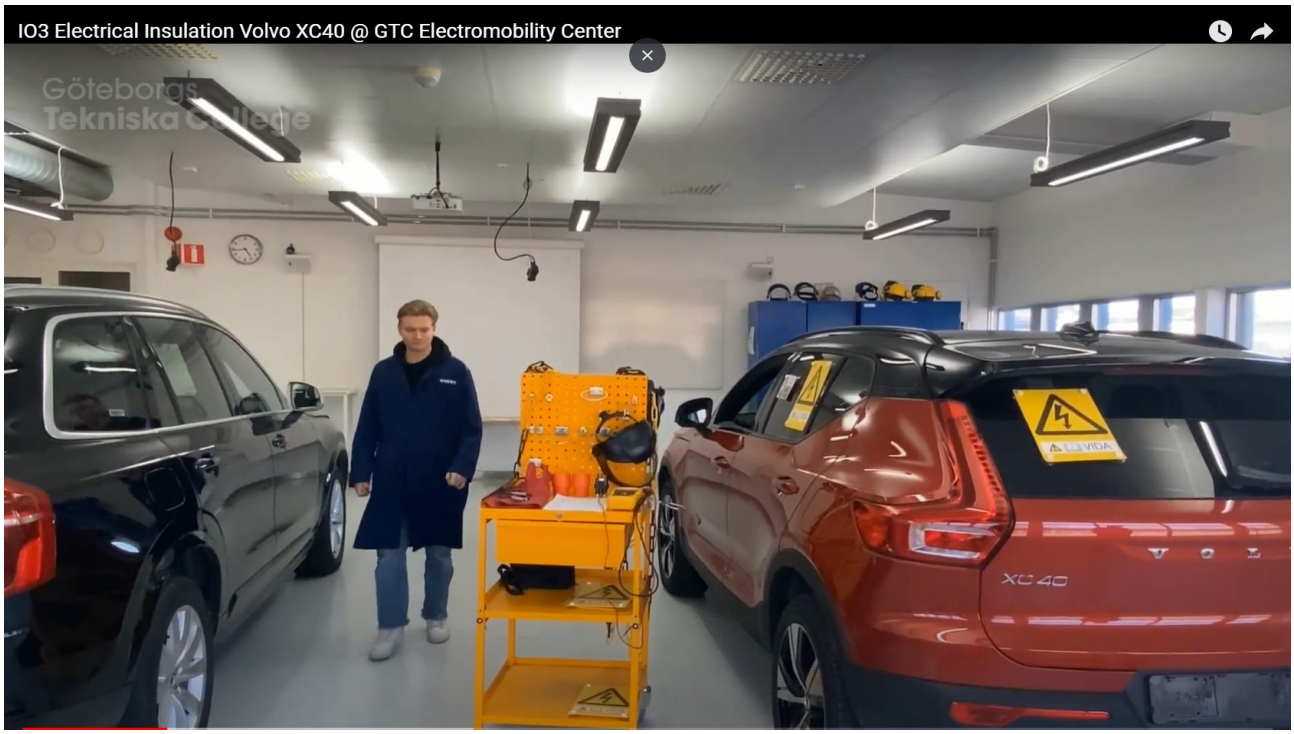
The multimeter insulation test identifies a preliminary operation that must be executed anytime an operator is performing an electrical task. Despite being a preliminary task, it should be executed only by instructed people because it involves electrical insulation.

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:



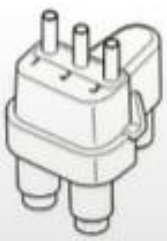
Step 1: insulation measurement for high voltage systems

Modell	År	Motor	Växellåda
XC40	2022	E40BV2	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 KΩ 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.

#Measurement 3

Important!

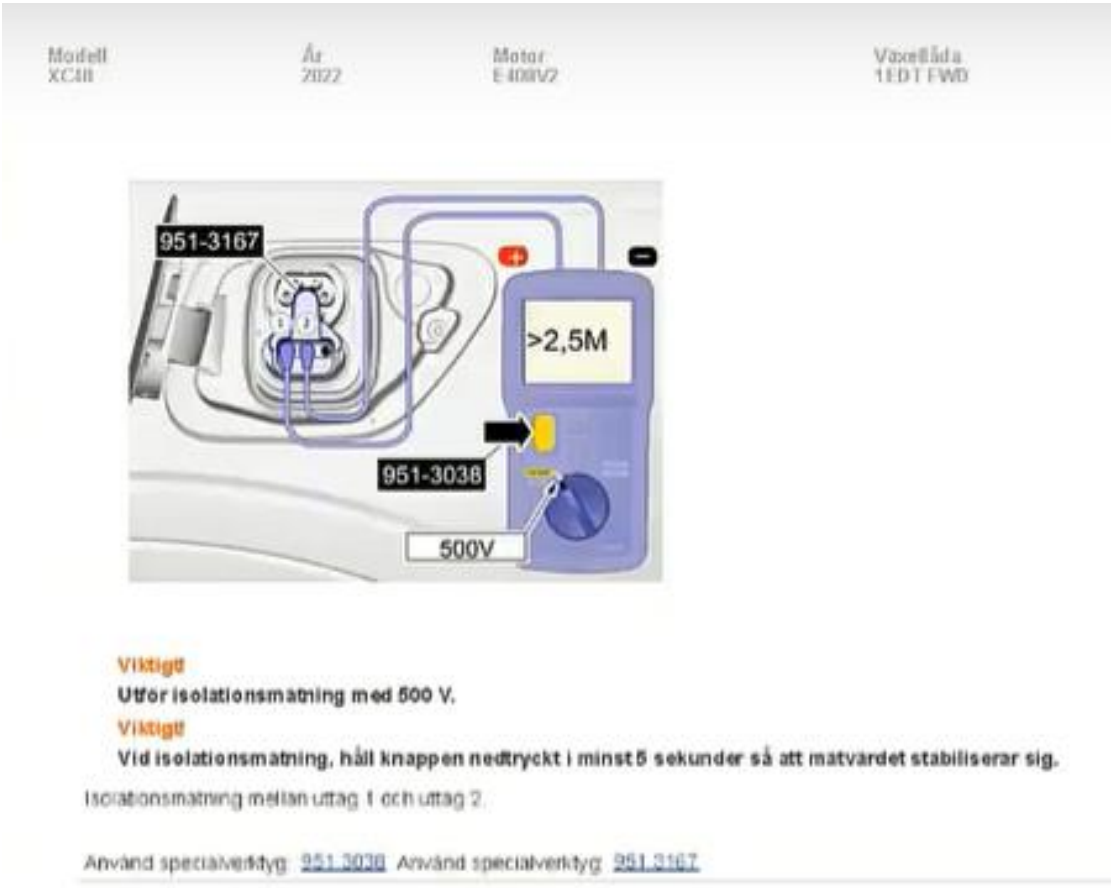
Perform the insulation measurement with 500V.

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



ⓒ 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:

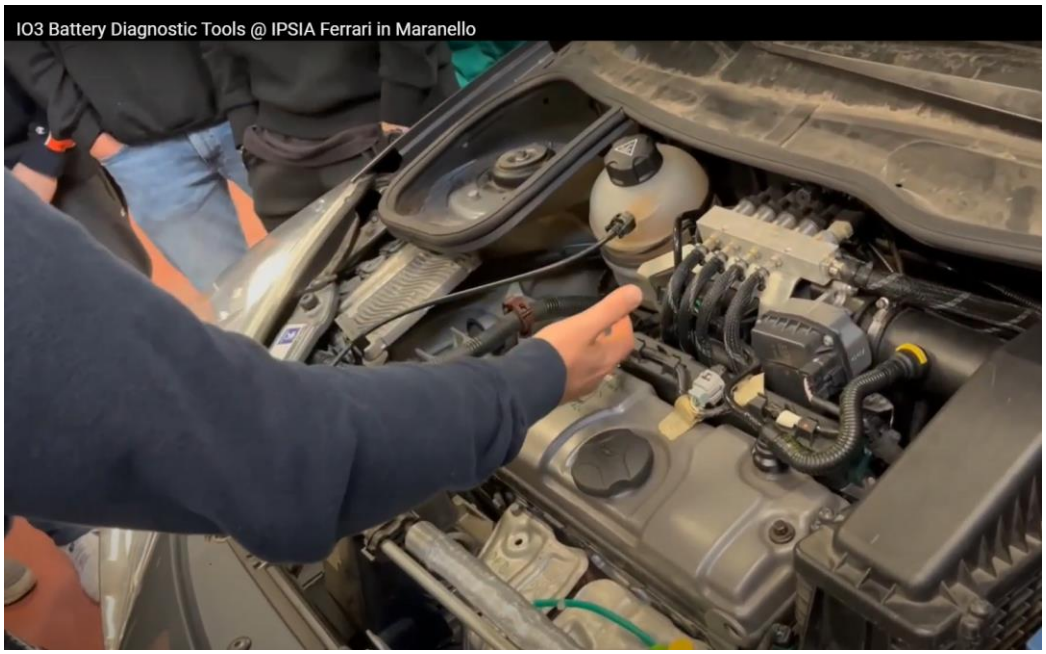
- engine parameters
- battery parameters
- control unit scans
- electrical schemes
- emission analysis
- lights settings
- brake pads efficiency & wear control

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;

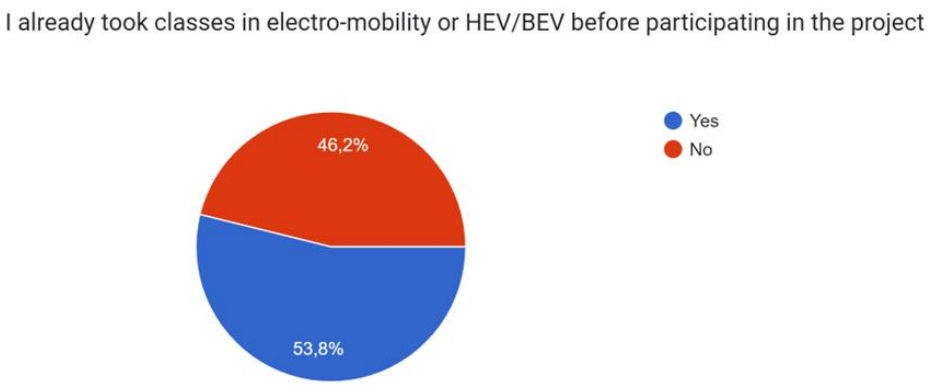
-the extent to which prior knowledge and skills were allowed learners to make the most out of the training program should be assessed;

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

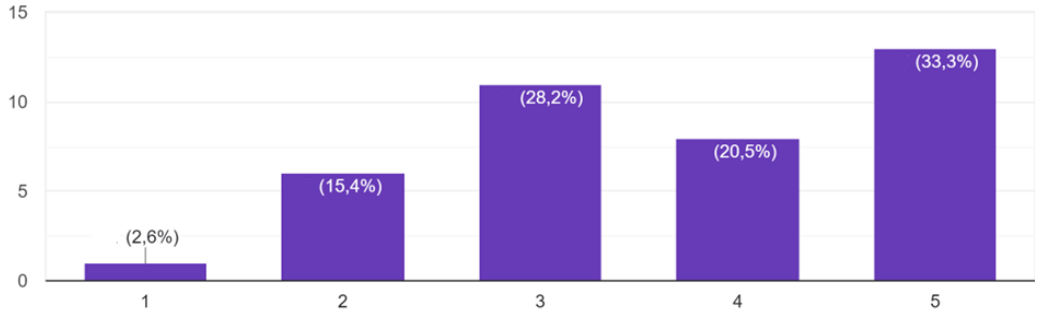
-the extent to which learners think to be suitably prepared to transition to the job market.

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.

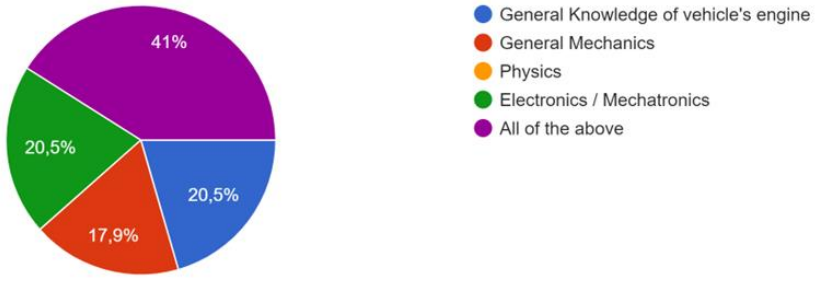
Answers with scale from 1 to 5 mean that respondents were asked to rate the sentence in the questions with a score from 1 (absolutely not) to 5 (absolutely yes).



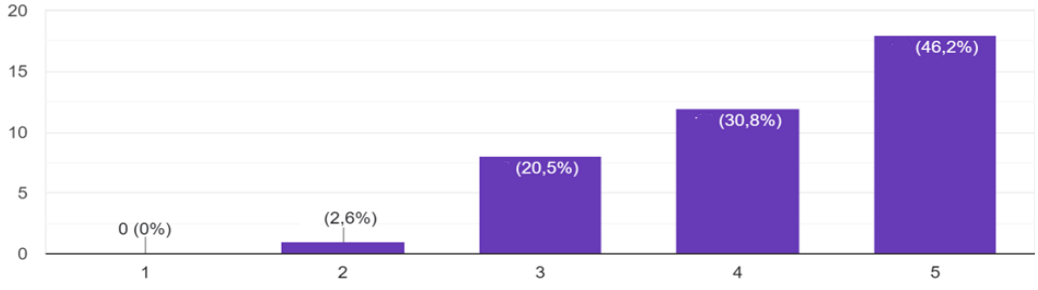
I think my previous knowledge & skills level was enough for me to take part in HEV/BEV testing



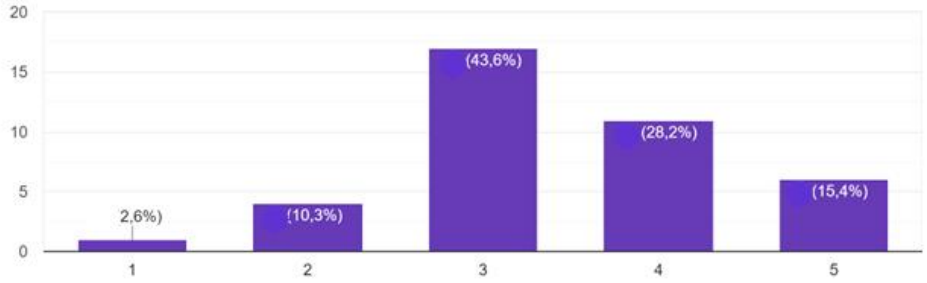
Which of the following was most helpful for you to make the most out of the HEV/BEV testing?



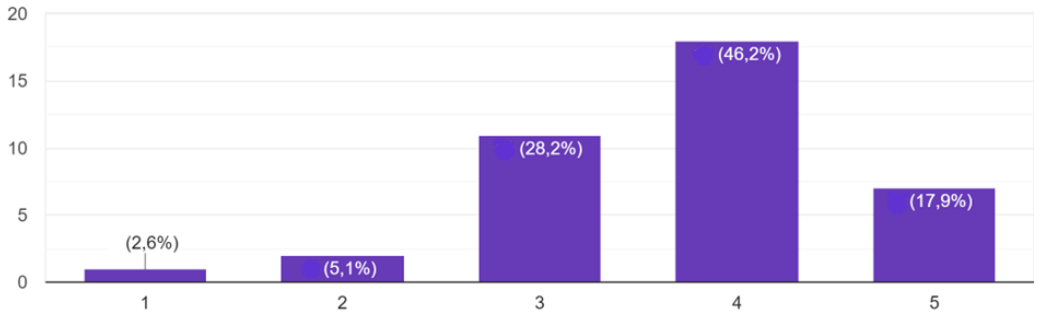
After the testing, I think I developed knowledge and skills about how a to work safely on an HEV/BEV vehicle



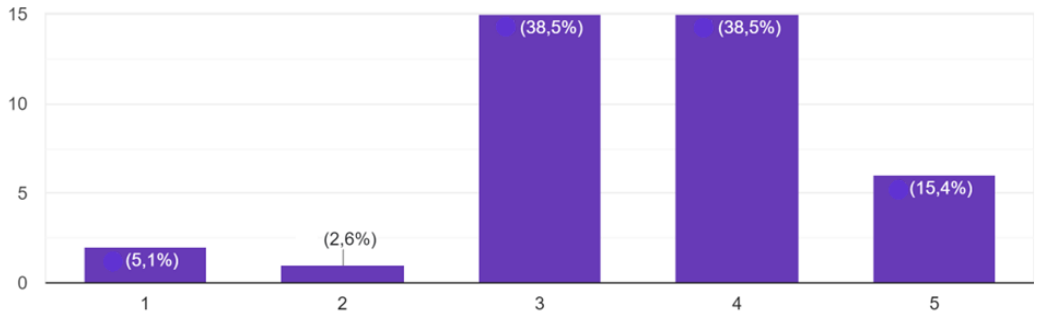
After the testing, I think I developed knowledge and skills about how to assemble & dissassemble the AC/DC inverter circuit of the car



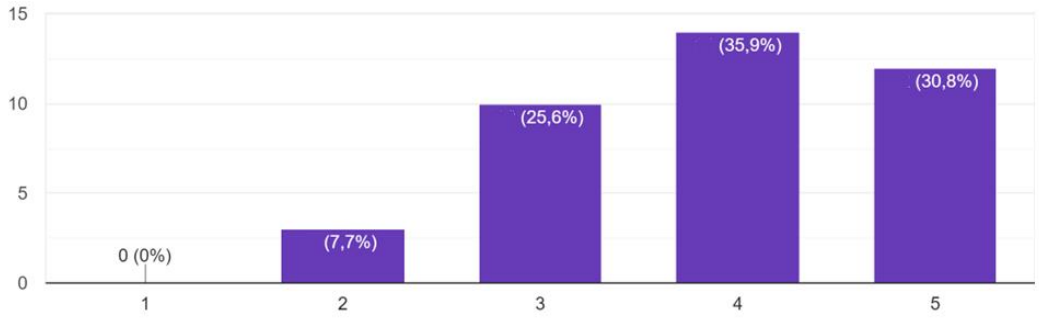
After the testing, I think I developed knowledge and skills about how to perform failure diagnosis & repair in a HEV/BEV system



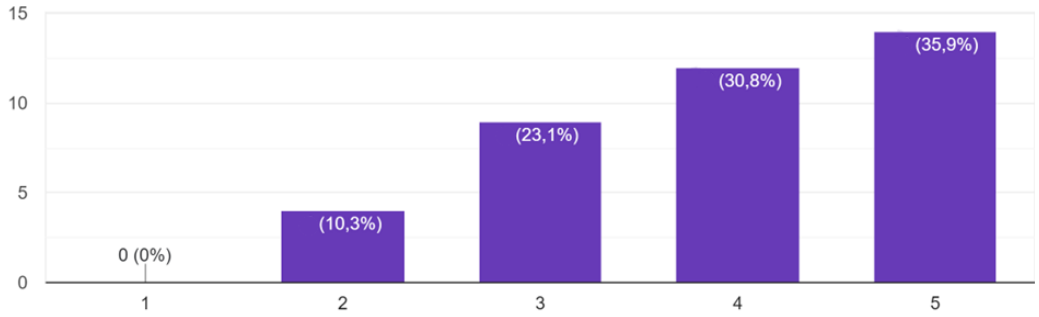
After the testing, I think I developed knowledge and skills about how to perform power unit maintenance in a HEV vehicle



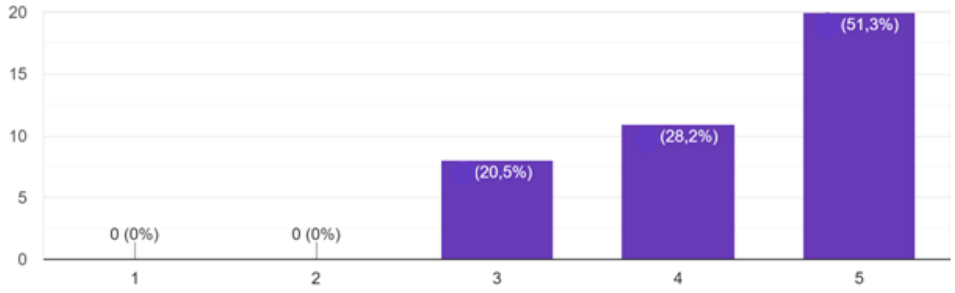
I think I am able to repeat by myself the procedures and work sequences I learned during the testing



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.