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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

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Training Program on avionics circuits maintenance on EV/HEV

Language: English

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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

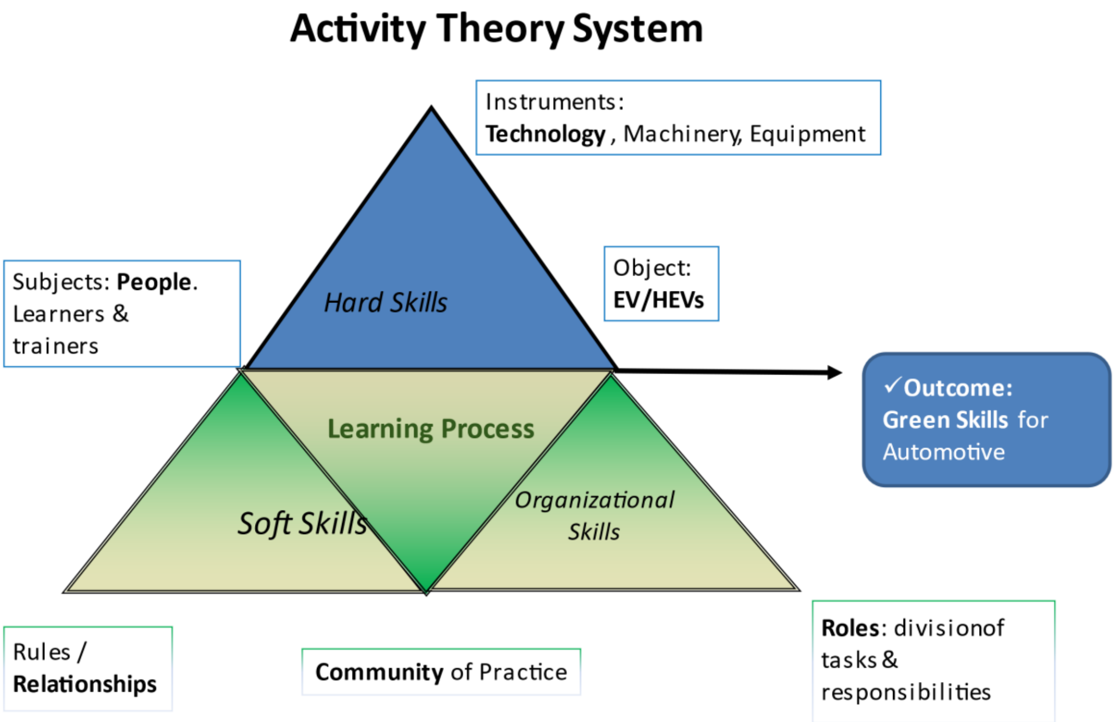
The training environment should make practical learning accessible and inclusive, and students should learn from work processes and organizational structure, as well as use technological assets that are the closest possible to the real workplace layout.

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.

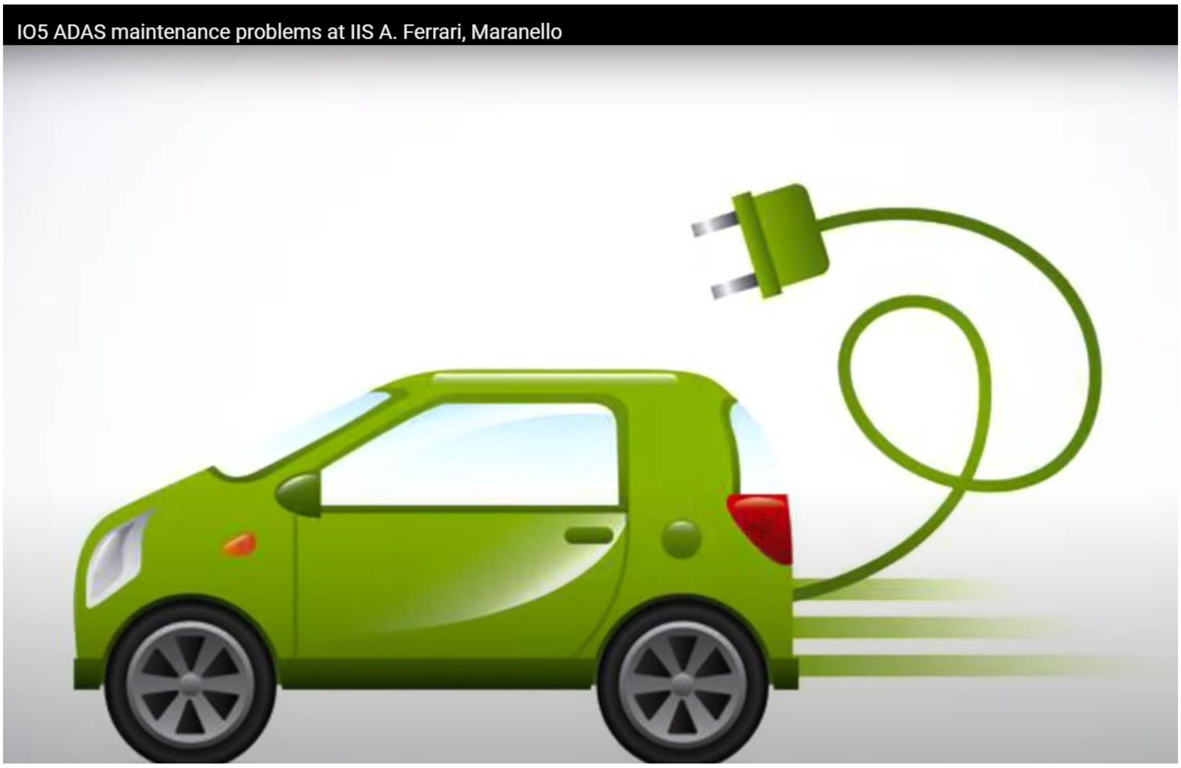
-periodical maintenance and recalibration of ADAS components. Sensors, radars and cameras that serve to receive and process data from the outside for ADAS are set to precise distance, height and position values already at the factory, i.e. when the car leaves the production lines. When replacing a body 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:

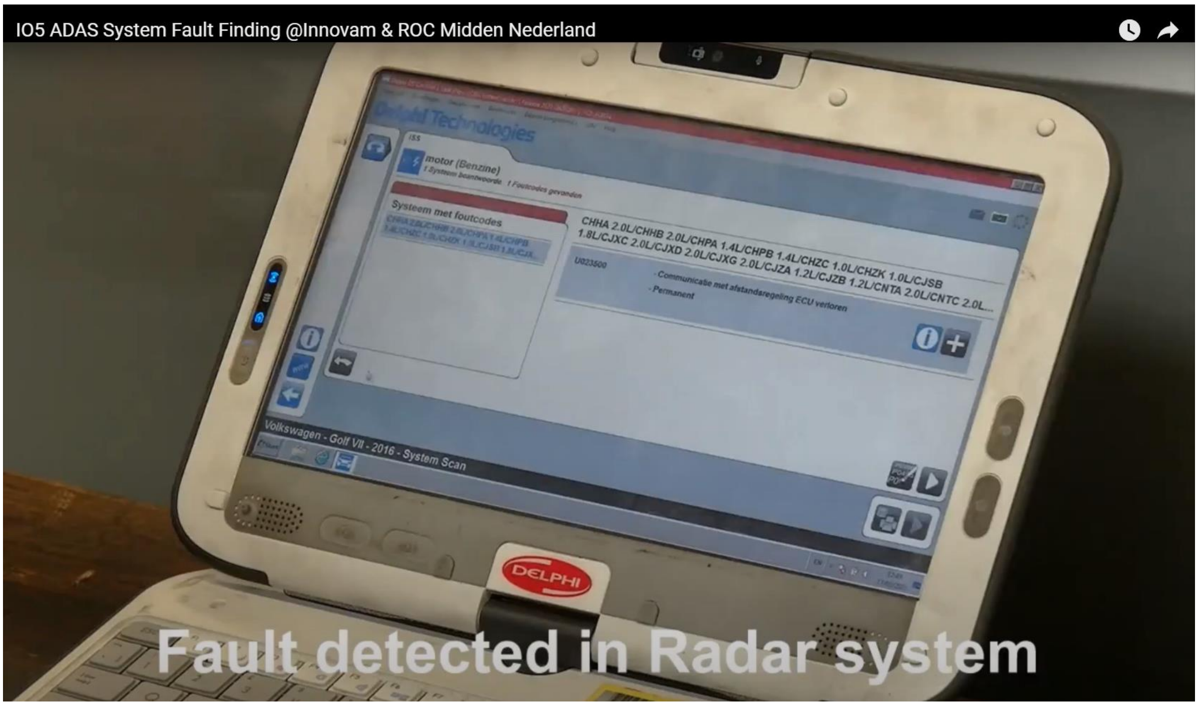
- Hybrid and electrical drivetrain
- Electric engines
- NEN9140 (EU regulation about electrical works)
- Charging Systems
- Inverter/Converter Battery Management

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).

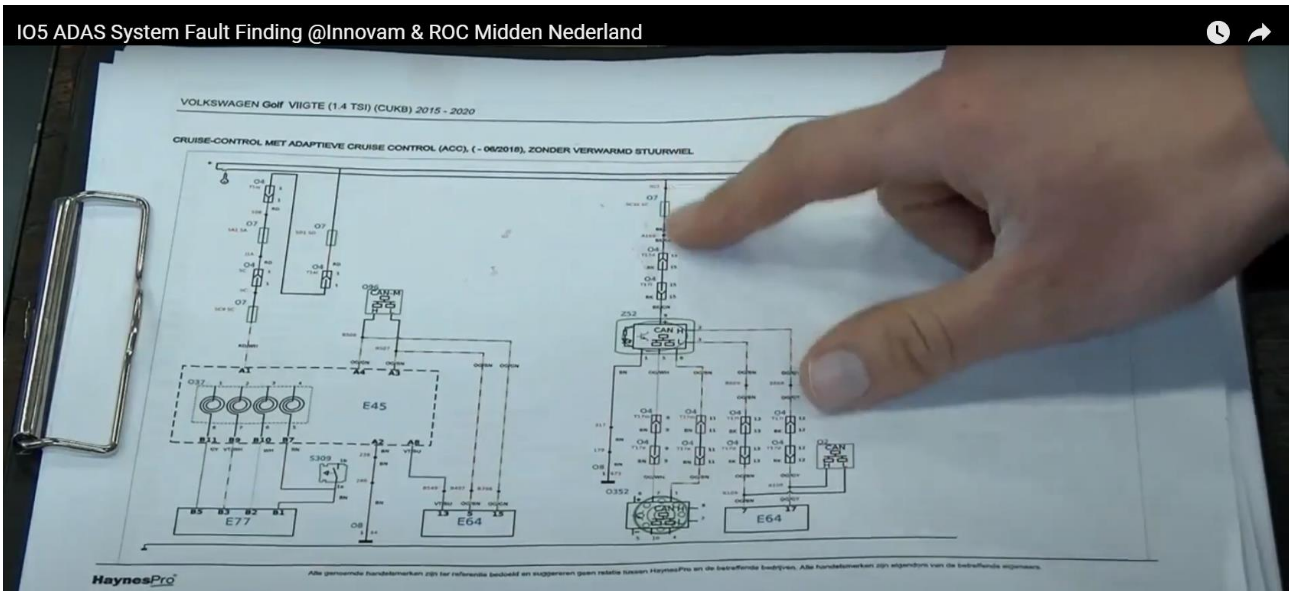
Entry Level Knowledge (Theoretical)	EQF level 3 Being able to recognize ADAS components Knowledge about how ADAS systems and components work Knowledge of diagnosis procedures Understanding electrical wiring diagrams
Hard Skills involved	Being able to operate a diagnostic tool Being able to follow diagnosis 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:

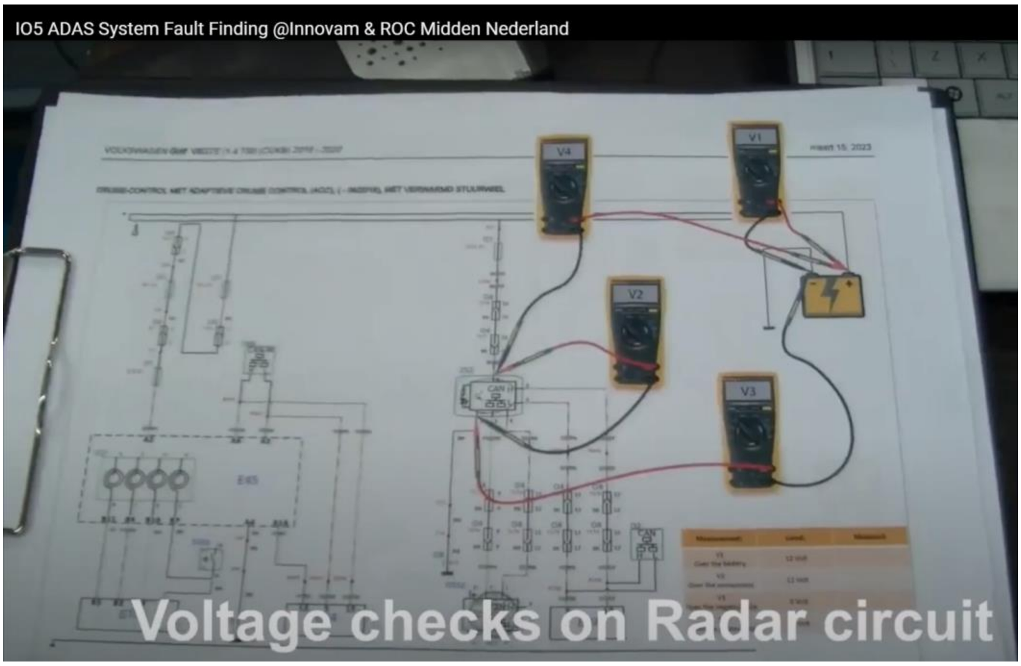


Procedure about repairing an ADAS component (vehicle radar) as shown in the video:

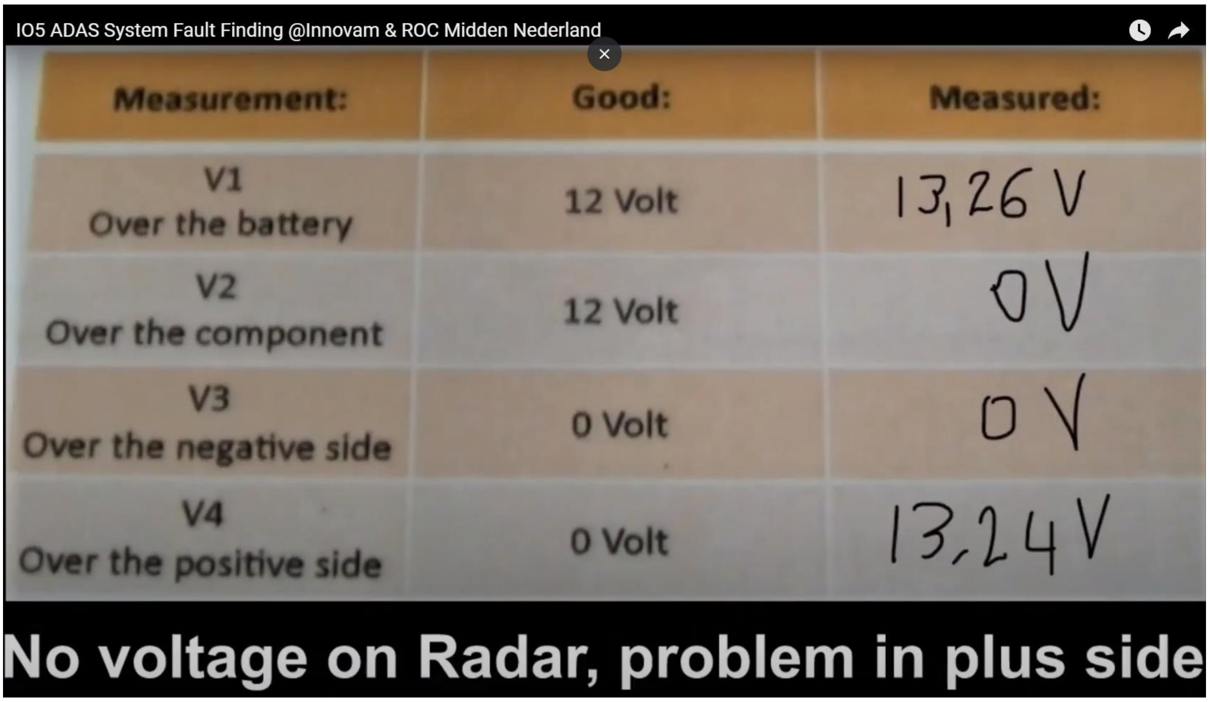
1) The trainee is given the task to prime the vehicle to detect any error message
2) A fault message appears: a failure is detected in the system
3) The Volkswagen OBD (Onboard diagnostic tool) is connected to the vehicle system and the scanning operations is started.
4) A fault is detected in the radar system
5) The trainer advices the learner to check the wiring system of the radar. The electrical wiring scheme of the radar is examined



6) Voltage checks are performed on the radar electrical circuits

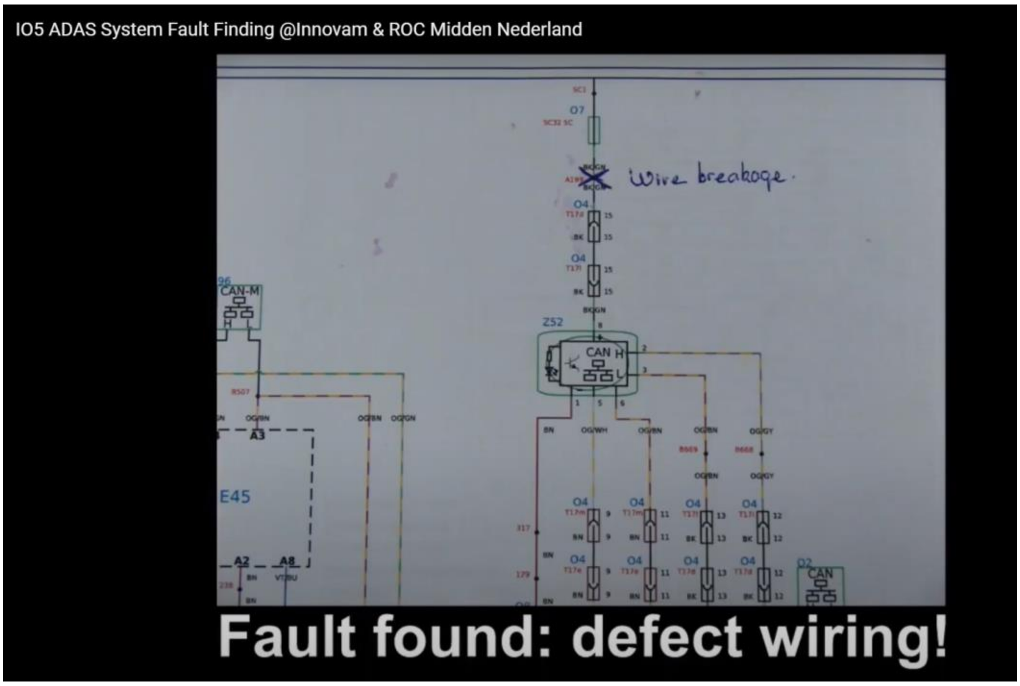


7) A scheme with the correct voltages that should be detected on each measurement terminal is provided to the trainee. The trainee is also given the task to perform all the measurements with a multimeter and to write the detected measurements down. As a result, no voltage in the radar is detected, so 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	*Remarks: guided instruction from the trainers was needed*
Students were able to perform tasks	YES	
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:

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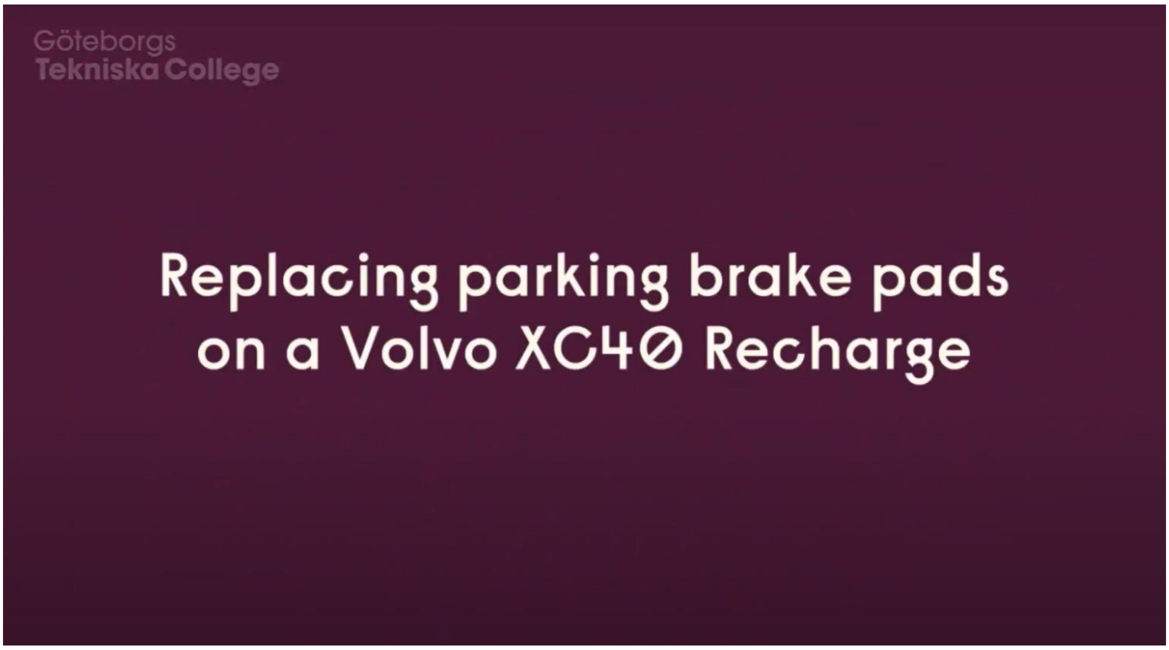


EVALUATION FORM		
Students' Performance		
Students were engaged and interested	YES	
Students were able to apply theoretical knowledge to practical tasks	YES	
Students were able to perform task	YES	

Students were able to work autonomously	In part	*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.

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

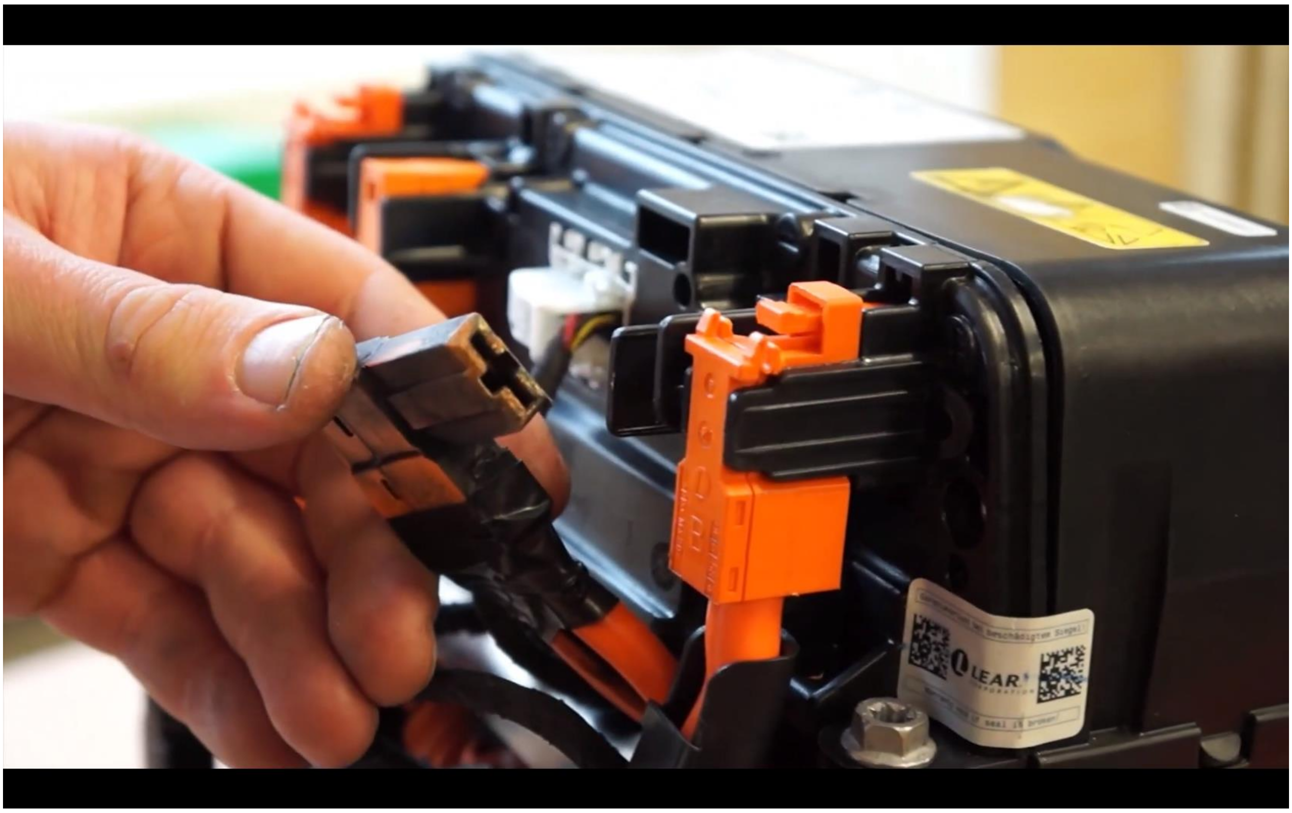
-Disconnecting all the battery plugs and accessing the battery modules place

-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

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

EQF level 5	Checking HV battery control units inside HV battery

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:

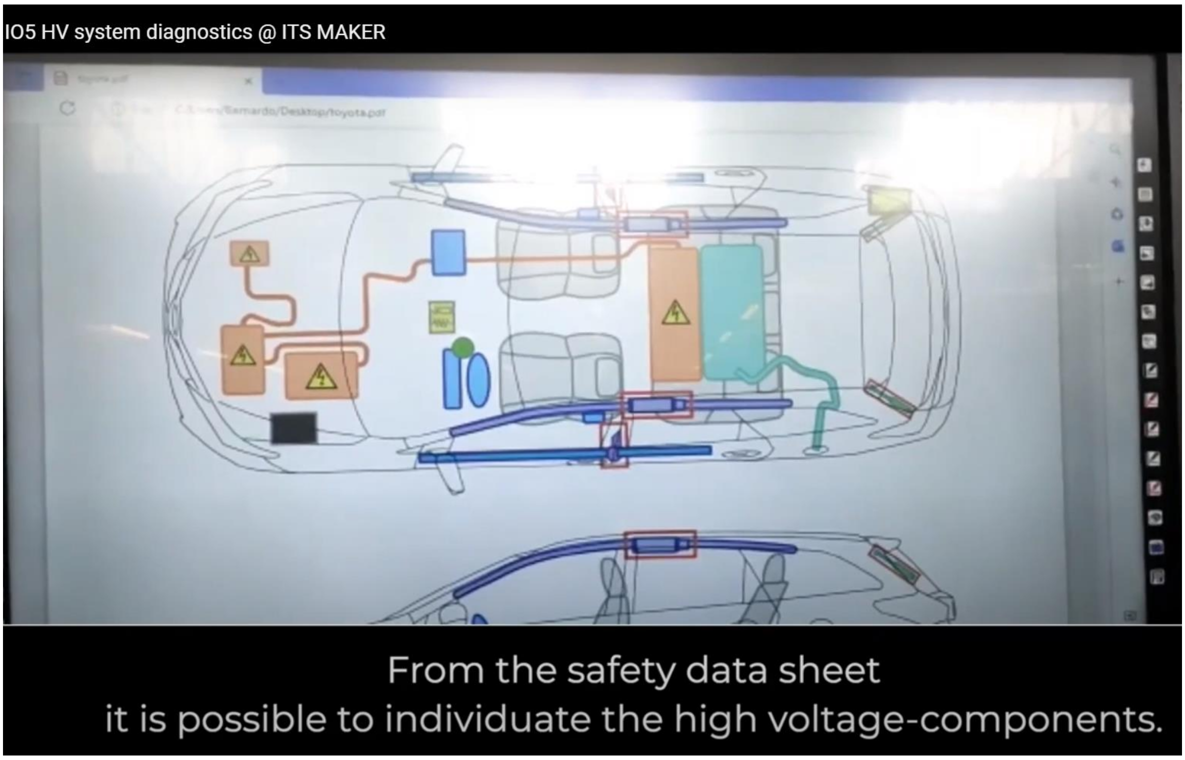
- Electrical schemes of vehicle circuits
- Electrical and electronic technologies and applications
- Installation and maintenance technologies and techniques

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;

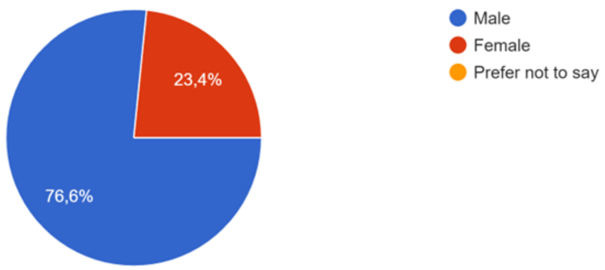
-the perception, on the learners' side, of actual development of e-mobility skills should be assessed;

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

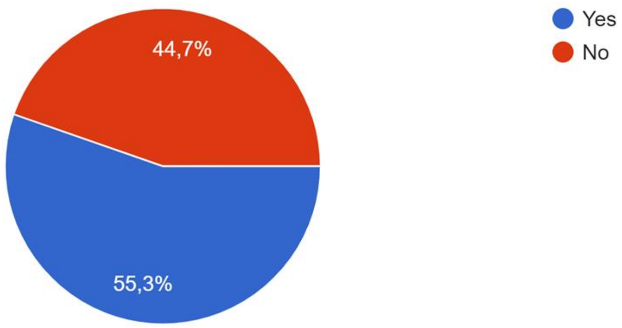
Examples of the collected feedback can be seen from the charts below, which report genderless aggregate data from all the countries and EQF levels involved.

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).

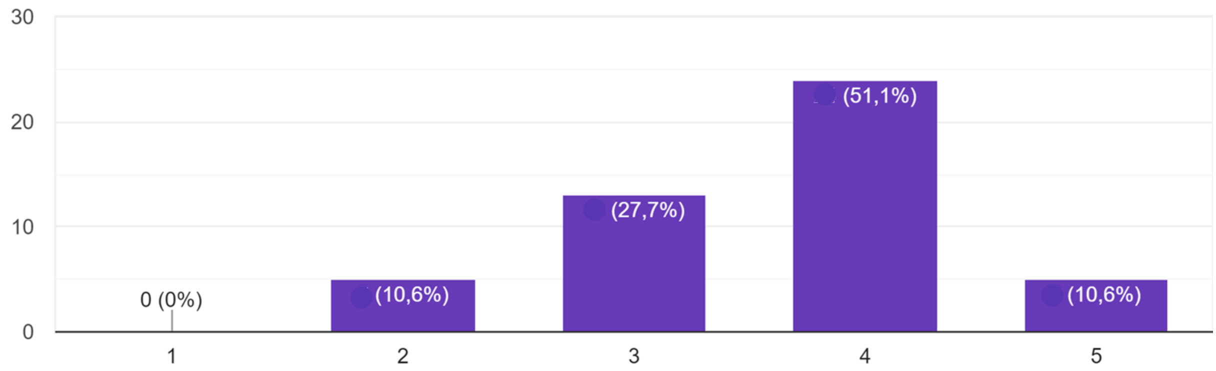
Your gender



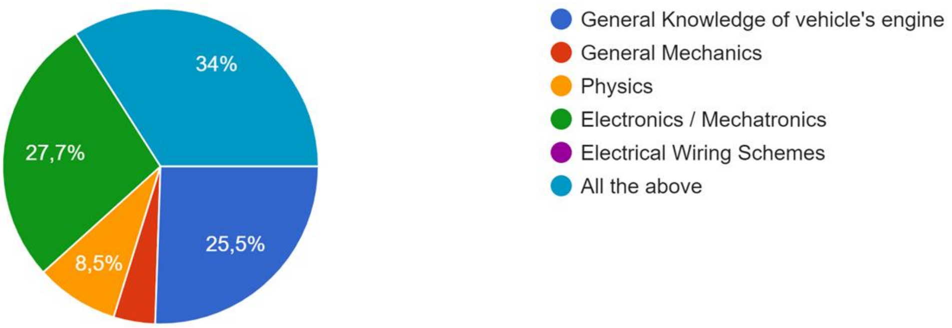
I already took classes in electro-mobility or HEV/BEV before participating in the project



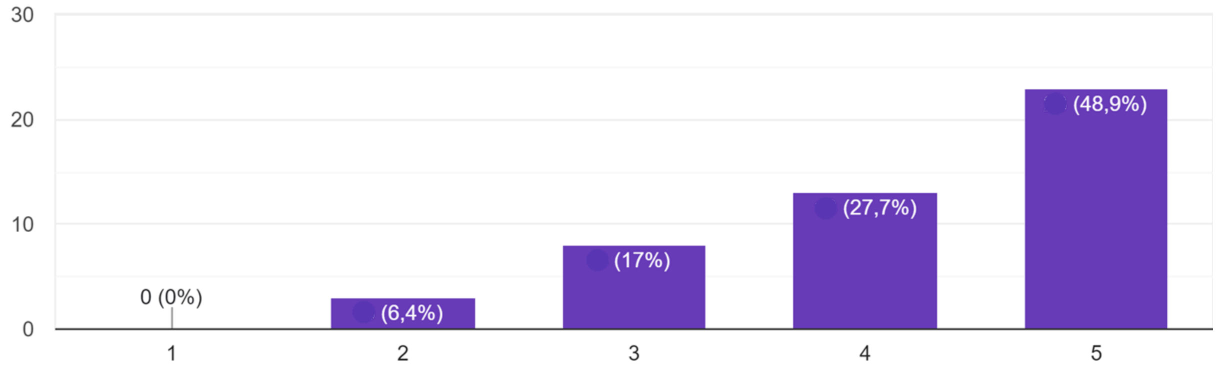
I think my previous knowledge & skills level was enough for me to take part in HEV/BEV testing



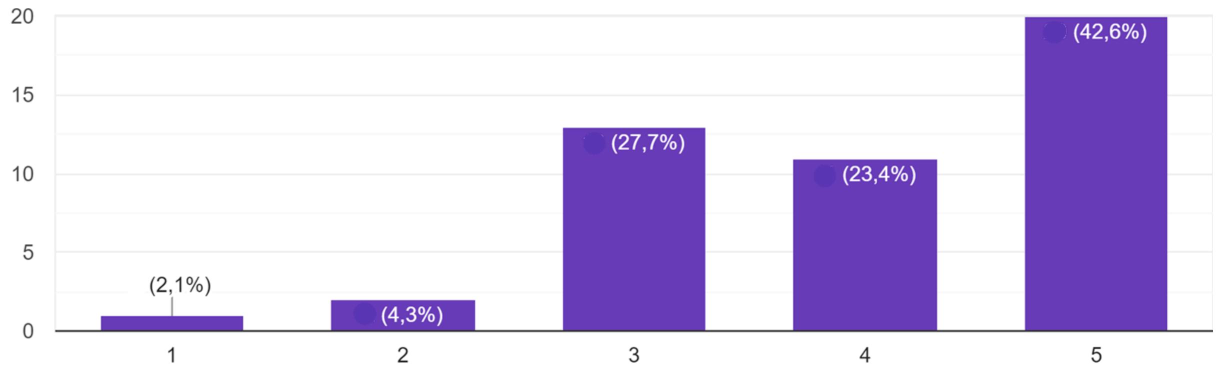
Which of the following was most helpful for you to make the most out of the HEV/BEV testing?



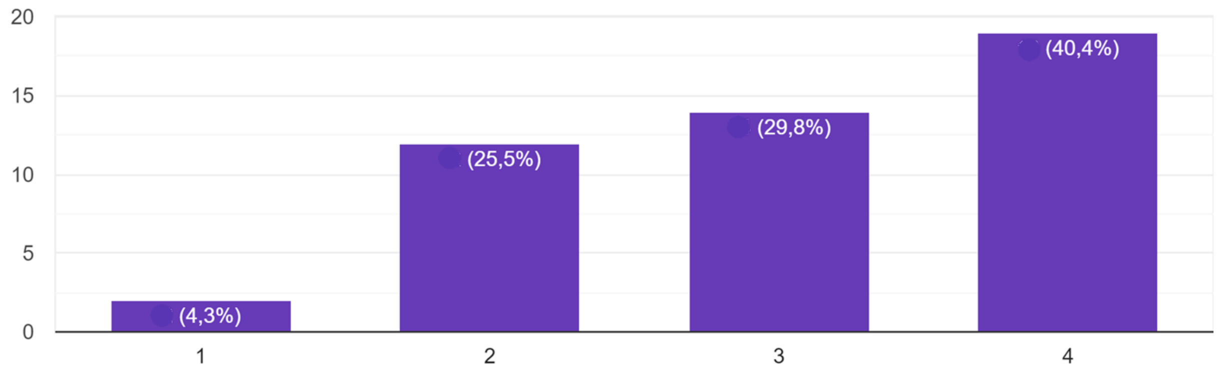
After the testing, I think I developed knowledge and skills about how a to work safely on an HEV/BEV vehicle



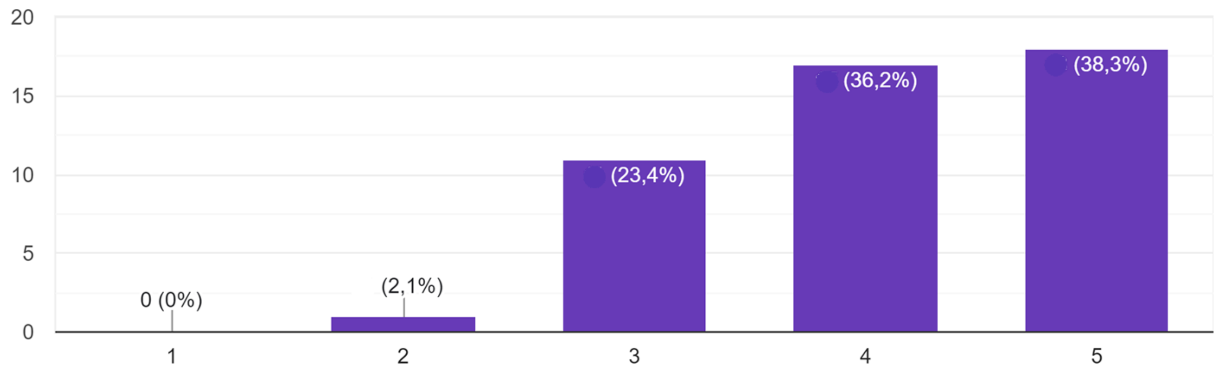
I think I can read electrical circuit wiring schemes



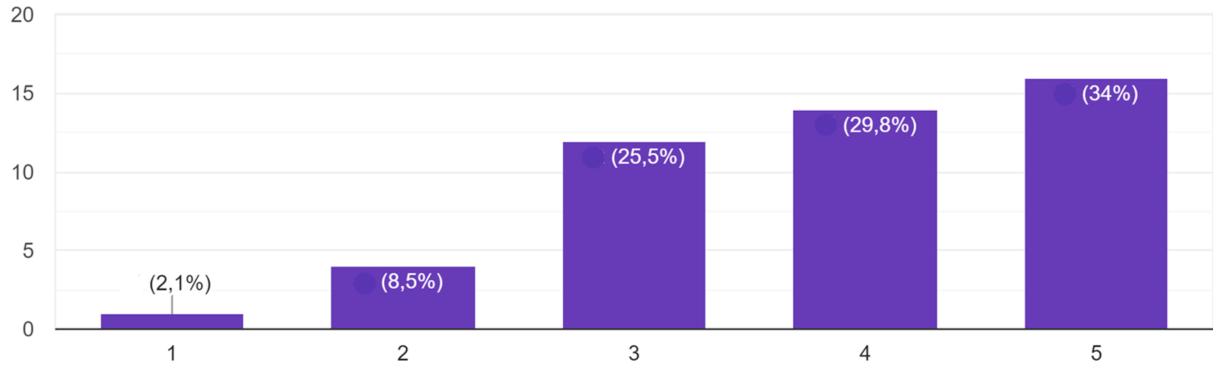
I developed knowledge and skills about ECU - Engine Control Units circuits damage & repair



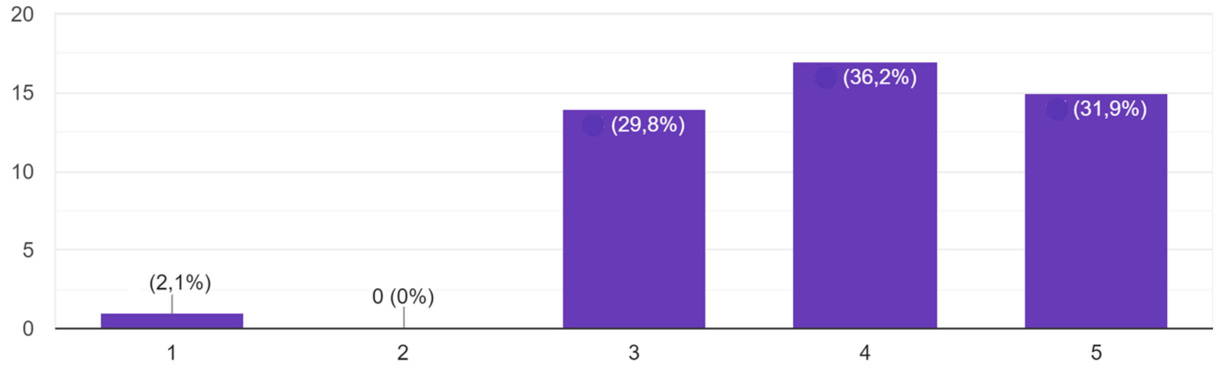
I developed knowledge and skills about ADAS calibration and diagnostics



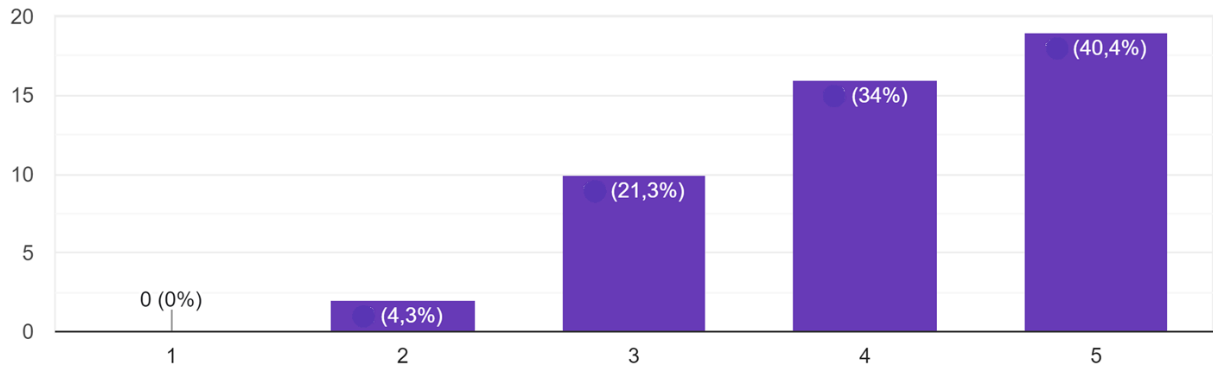
I developed knowledge and skills about how to perform failure diagnosis & repair in a EV/HEV system



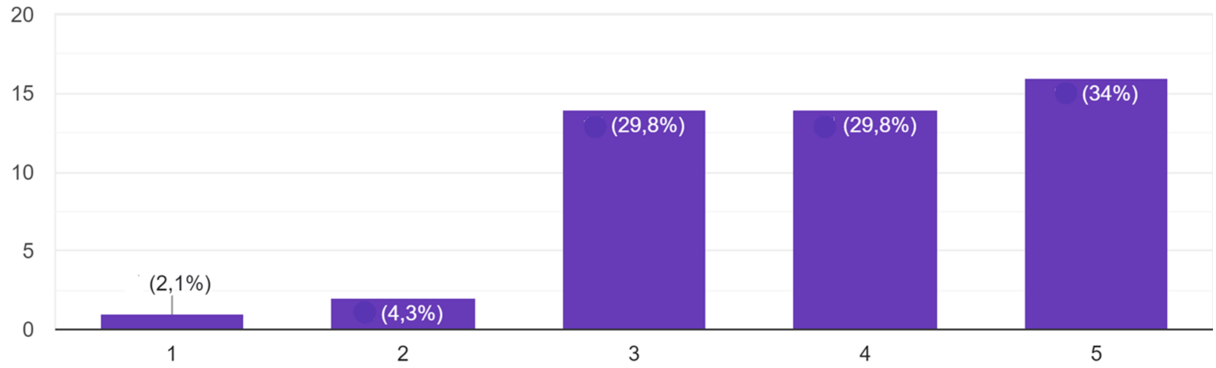
I developed knowledge and skills about assisted braking systems in a EV/HEV system



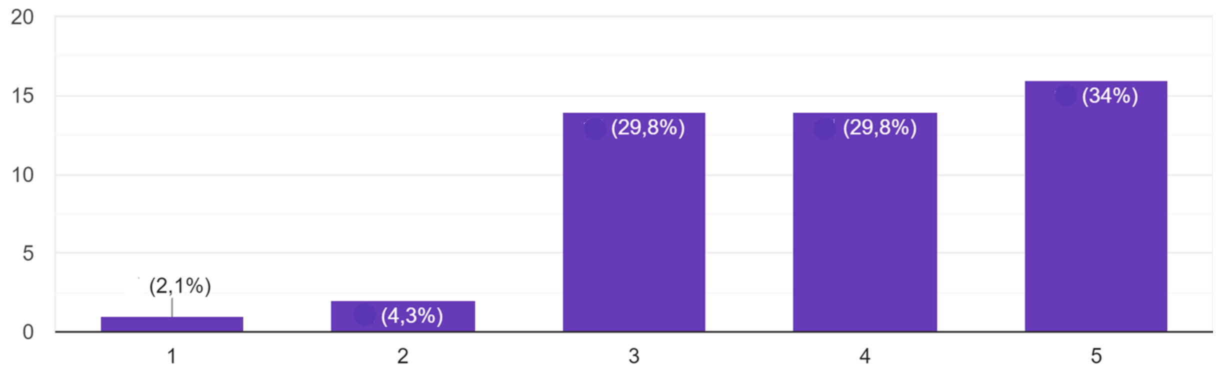
I developed knowledge and skills about EV/HEV battery

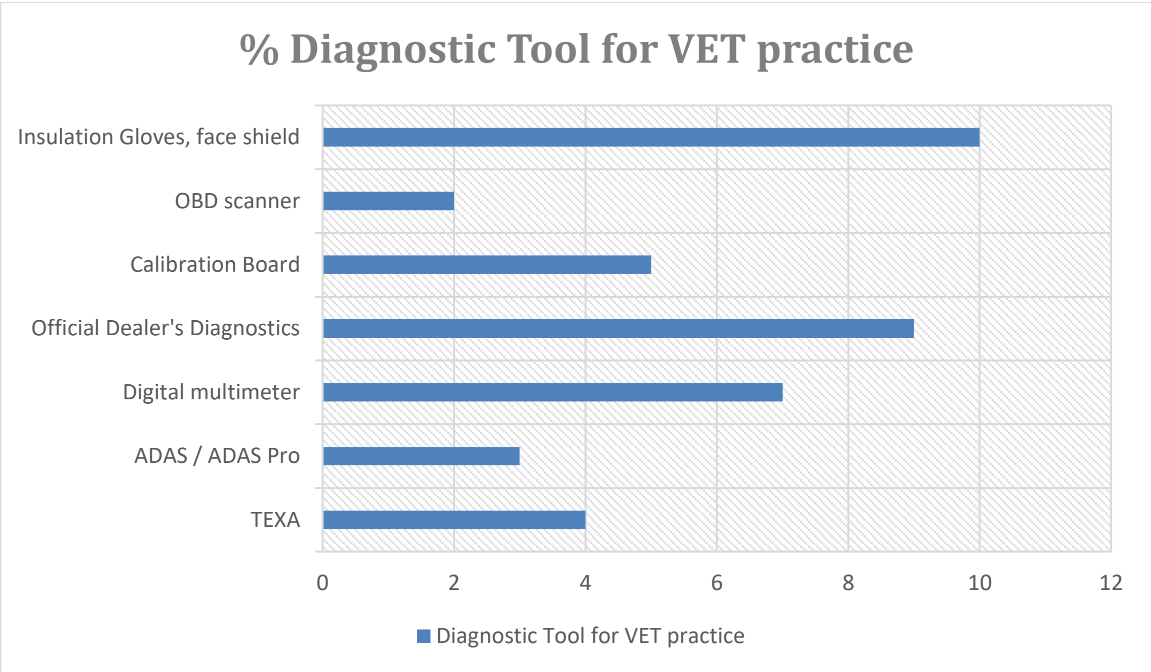


I developed skills in using EV/HEV diagnostic tools

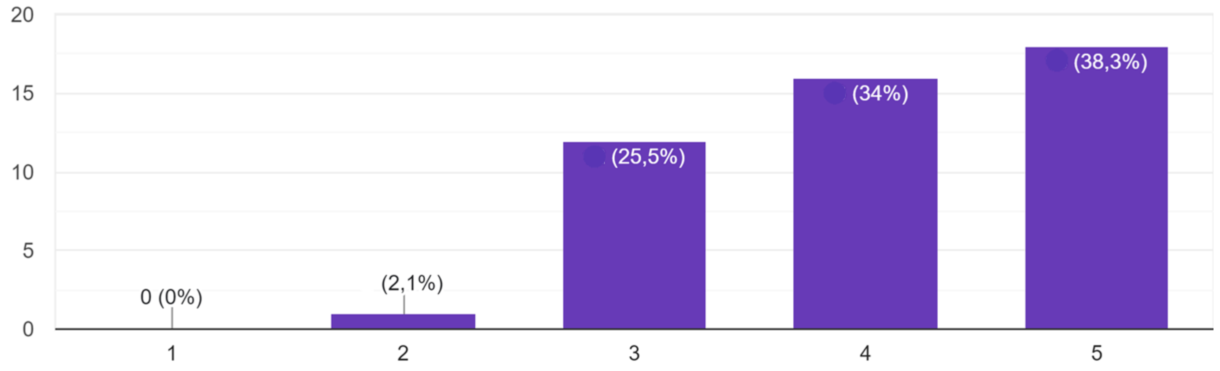


I developed skills in using EV/HEV diagnostic tools

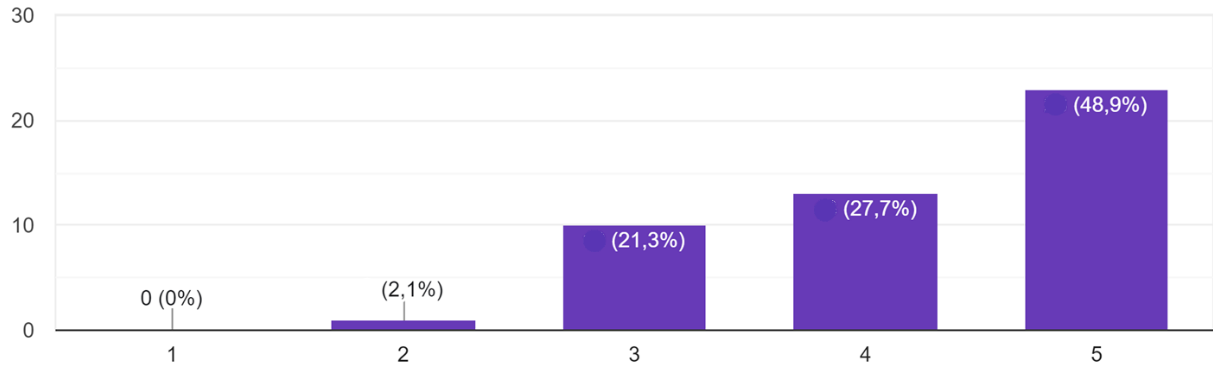




I think I have better ideas about how a company workplace or a production plant or car workshops works



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 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.