Erasmus+ KA220-VET

Cooperation partnerships in vocational education and training

Development of VR/AR Assisted Digital Training Materials for Hybrid and Electric Vehicles (DTM4HEVs)

[2023-1-TR01-KA220-VET-000152218]

HEVs Training Course Curriculum and Content

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2024 Bursa, Türkiye

Funding diclaimer: This project has been funded with support from the European Commission. This communication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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CURRICULUM DEVELOPMENT METHODOLOGY

The common HEVs training courses and course contents have been examined in detail and their shared learning outcomes constitute the basis of the curriculum development stage of this project. The stages in the process of curriculum development can be seen in Figure 1.

Figure 1. Stages in the Process of Curriculum Development

Throughout the curriculum, content and scenario (storyboard) development process, the program development team, consisting of project members, academics and stakeholder representatives, supported by scientific datas will be designed that maintained its up-to-datedness currency by considering national and international criteria. In the teaching of some subjects, instead of covering the whole content, the method of teaching the related module is adopted. The following sorted modules were identified to develop VR/AR supported content based on draft project proposal.

Module 1: Introduction to hybrid and electric vehicles

Module 2: Battery and energy storage systems

Module 3: Automotive Electronics

Module 4: HEVs and EVs diagnostic

CONTENT DEVELOPMENT METHODOLOGY

The curriculum development team determined the necessary criteria for the course by considering the following specifications:

- A structure to meet the basic demands of the sector;
- Compatibility with continuous development;
- Flexibility in timing and educational structure; and
- A modular approach.

Handling all priority issues, the program development team has initially sorted them out according to their fields and results of the needs analyses; the process of integration of the issues has started. In the terminal stage, modular structure and course contents have been formed by taking into consideration the contents of the similar courses or the contents of the training in the vocational education institutions.

The fact that the individuals who would be attending the course had different backgrounds in

terms of knowledge and skills that makes it difficult to prepare content suitable for everyone. However, the general philosophy of the training programme is based on competence so an individual completing a course should master the required knowledge and skills in that module. This priority was specifically considered when planning the course content and the details of theoretical and practical training classes. To this end, the training course was designed to be brief, competency-based, target-oriented, and student-centred.

Following the determined basic criteria and methodology, the stage of determining main projections for the content, priority, time and material development forecasts were passed. At this stage, the process was carried out as follows:

- Determining the course outcomes by examining the content of the HEVs training courses (learning outcomes),

- Determining the main and sub-topics of the training modules,

- Determining an appropriate V/AR method to teach according to modules and needs analysis of sub-topics

- Determining the content and class hours of the module

The development of an AR/VR application to support the T&L of HEVs learners in education and industry. Using a multi-disciplinary design-based research methodology (Figure 2), this European (Türkiye, Romania, Bulgaria) funded research project combines pedagogy and technology to approach HEVs education problems; and to develop an AR/VR education solution to address learning difficulties within the different critical HEVs categories will be identified.

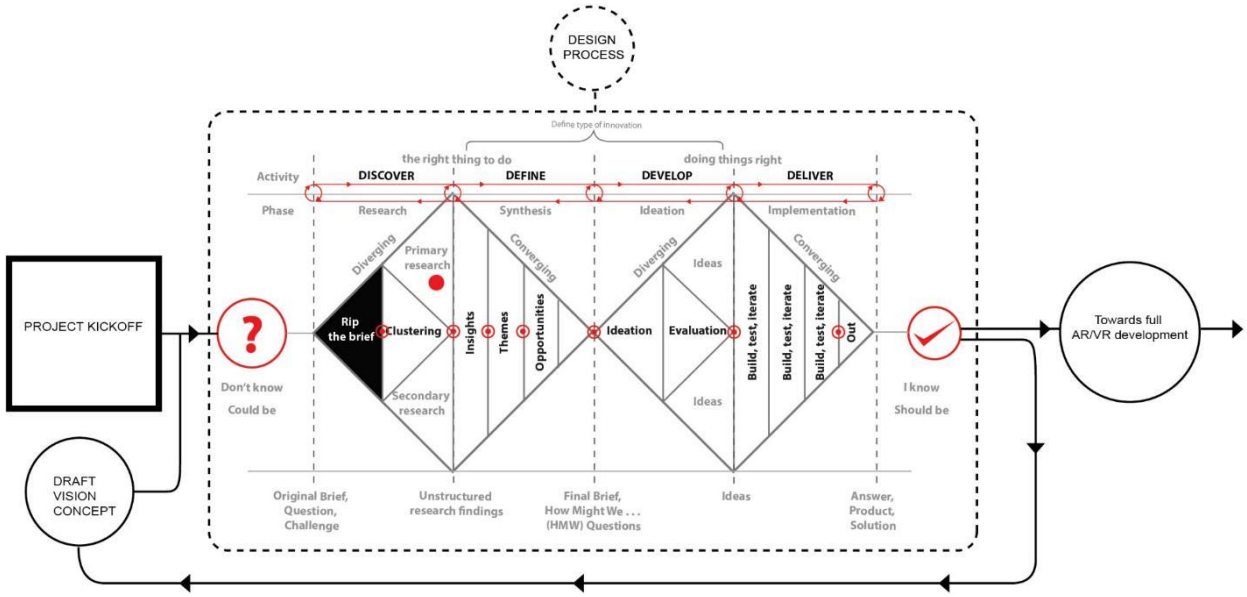

Figure 2.Multi-disciplinary design-based research methodology

This development is based on findings from an international study in three different categories covering the perception of HEVs education, assessing of HEVs knowledge and ability, and expectations of HEVs education. This research project also covers the difficulties and good practices of multi-disciplinary teams for developing HEVs and AR/VR contents where the approaches to T&L may differ between practices.

Developing Modules, Course Content and Learning Outcomes

During the module development phase, a multi-national curriculum development commission will established under the leadership of academics among the project team who have expertise in the field of HEVs training. Content and learning outcomes will be determined in line with the basic criteria given in the method section (meeting sector expectations, compatibility with continuous development, flexibility in timing and educational structure, and modular approach.) and as a result of the priorities that were revealed from the needs analysis. Table 1 shows the format of the contents developed according to the module topics. Also Table 2 shows the draft format of the Learning/Teaching methods for VR/AR supported HEVs training.

Table 1. Format for Developed Modules

Module Title		
Course Content		
Learning Outcomes	1.1	**Learners are able to:**
	1.2	
	1.3	
	…	
Course hours		

Table 2. Format for L&T methods

Learning Teaching Methods	**Learning Methods for Individual Users** ✓ First watch related video or animation / visualization and understand basis of the subjects. ✓ Use your AR apps to see these subjects in 3D environment ✓ Use your mobile device to see related VR apps to practice these subjects in 3D environment via using VR glasses, **Teaching Methods for Trainers** These applications and animations should be used as supporting materials during theoretical lecture to teach the course content. Suggested methods are: ✓ Present the content via PowerPoint or other presentation tools, ✓ Play / show video or animation wherever a visualization opportunity is emerged while presenting the content, ✓ Learners can use their own AR apps to create these subjects as 3D environment where possible, ✓ Or demonstrate how to use AR apps in detail via projector , ✓ Learners can use their own mobile device to see related VR apps to create

	these subjects as 3D environment via using VR glasses, ✓ Or trainers can use VR apps via HTC vive with the learners to understand related subject in 3D environment
How to Use	**Use of Animations:** Before using the AR app, users should watch video or animation/visualization that is related to work to understand basis of the topics. **Use of AR apps:** A virtual object would be superimposed over a live video feed from a camera of a mobile device. The ARCore app used to develop this application can only work with new mobile phones that run Android 12.0+ or higher operating systems. **Use of VR apps:** The requirements for students/teachers for VR apps would be the HTC VIVE Virtual Reality System or VR Glasses. **Use of VR with cardboards:** VR application is run on a mobile phone which is inserted into a cardboard. Then choose your HEVs subject from menu and follow the instructions.

DRAFT
COURSE CURRICULUM
AND
CONTENTS

Module Code: HEVS1
Module Title: Introduction to hybrid and electric vehicles

Course Content	**1. Electric and Hybrid Vehicle Technology** 1.1. Electro-Mobility Concepts 1.2. Hybrid Electric (HEV) vehicles 1.3. Electric (EV) vehicles 1.4. Comparison of internal combustion engine vehicles and electric vehicles **2. Hybrid Vehicle Technologies** 2.1. Types and structural features 2.2. Working principles 2.3. High Voltage Components of Hybrid Vehicles, 2.4. Hybrid Vehicle Control Systems 2.5. Powertrain Systems 2.6. 48V Hybrid Vehicle System **3. Electric Vehicle Technologies** 3.1. Types and structural features 3.2. Working principles 3.3. Driving Systems 3.4. Power Electronics 3.5. Electric motors 3.6. Batteries 3.7. Self Safe Vehicles (ECE-R100) 3.7.1. High Voltage Security Systems 3.7.2. Pilot Line-Interlock 3.7.3. Equipotential Circuits 3.7.4. Insulation Resistance and Monitoring Module (IMD) 3.7.5. Collision System 3.7.6. Service plug 4. **Electrical Machines** 4.1. Torque and Power Characteristics, Motor Efficiencies 4.2. Types and structural features of electrical machines 4.3. AC Alternating Current Motors 4.4. Traction Motors Used in Electric Vehicles 4.4.1. Asynchronous Motors 4.4.2. Synchronous Motors 4.4.3. DC Direct Current Motors 4.4.4. Reluctance Motors **5. Motor Control Systems (EV Power Electronics)** 5.1. Structural features and operation of Motor Control systems 5.2. Power electronic systems 5.2.1. İnverters 5.2.2. Boost converters-Buck converters **6. High Voltage Batteries used in HEV and EV vehicles** 6.1. Structural features and types of high voltage batteries 6.2. HEV and EV vehicles battery charging connector-charging units **7. Other Systems** 7.1. Thermal Management Systems 7.1.1.Battery Thermal Management System 7.1.2.Inverter-Electric Motor Cooling System 7.1.3.In-vehicle air conditioning systems 7.2. Steering Systems 7.3. Brake Systems

Learning Outcomes	1.1	**At the end of this training, learners:** • Knows the structure and operation of Hybrid Electric Vehicles, • Knows electric vehicle structures and types, • Knows the structure and operation of Battery Electric Vehicles
	1.2	**At the end of this training, learners:** • Knows the types and systems of hybrid vehicles and the operation of these systems
	1.3	**At the end of this training, learners:** • Knows the systems of electric vehicles and the operation of these systems, • Knows the types of high voltage security systems, • Knows the structure and operation of high voltage security systems
	1.4	**At the end of this training, learners:** • Knows the types, structure and operation of electrical machines, • Explains the operation of the electrical machine
	1.5	**At the end of this training, learners:** • Knows motor control systems, • Knows the types and operation of inverters, • Knows the types and operation of conventors
	1.6	**At the end of this training, learners:** • High Voltage Batteries used in HEV and EV vehicles • Knows high voltage batteries in hybrid and electric vehicles
	1.7	**At the end of this training, learners:** • List other systems in hybrid and electric vehicles, • Explain Air Conditioning, Brake, Steering and Thermal management systems, • Knows the operation of heat pumps and liquid cooling systems, • Knows how to steal heating/cooling systems in hybrid and electric vehicles.
Course Hours	40 Hours	

Module Code: HEVS2
Module Title: Battery and energy storage systems

<table>
<tr><td>Course Content</td><td colspan="2">1. Energy Storage Systems
1.1. Chemical batteries
1.2. Super capacitors
1.3. Flywheels
1.4. Hydraulic systems
2. Battery Performance Characteristics
2.1. Capacity
2.2. Specific Power
2.3. Specific Energy
2.4. Energy Density
2.5. State of Charge-SoC
2.6. State of Function-SoF
2.7. Depth of Discharge-DoD
2.8. Cycle Life
3. High Voltage Battery Technology
3.1. Development and Types of Batteries
3.2. Lead-acid batteries
3.3. Nickel based batteries
3.4. Lithium based batteries
3.5. Sodium based batteries
4. Battery Architecture (Design)
4.1. Cell types
4.2. Package design
4.2.1. Module-package model
4.2.2. Cell-pack model
5. Battery Management Systems (BMS)
5.1. Structure (Master-Slave) Duties (Sensors)
5.2. Relays/Contactors and Precharge Circuit
5.3. Thermal systems (Heating-Cooling)
6. Battery Life
6.1. Battery Transportation Procedures
6.2. Thermal Runaway and Fire
6.3. Waste Management and Recycling
7. Battery Malfunctions and Maintenance
7.1. High voltage battery fault codes
7.2. Malfunctions caused by Mechanical, Thermal, Chemical degradation
8. Fuel Cells
8.1. FCEV
8.2. Hydrogen Fuel
8.3. Working Principles
8.4. Types
9. Charging Methods and Systems
9.1. Charging Methods (AC, DC, Wireless, Battery Replacement)
9.2. Charging Modes
9.3. Charging Connectors
9.4. Wireless Charging System</td></tr>
<tr><td></td><td>2.1</td><td>At the end of this training, learners:
• Knows energy storage systems and their types.
• Knows chemical batteries, supercapacitors, flywheels and hydraulic systems</td></tr>
</table>

Learning Outcomes	2.2	**At the end of this training, learners:** • Knows the performance characteristics of batteries, • Knows the basic concepts of capacity, specific power, specific energy, energy density, cycle life, state of charge, depth of discharge and state of health
	2.3	**At the end of this training, learners:** • Knows the development of high voltage battery technology and battery types, • Knows lead-acid, nickel-based, lithium-based and sodium-based high voltage batteries.
	2.4	**At the end of this training, learners:** • Knows battery architecture and design, • Knows battery cell types. • Makes the necessary calculations for battery pack design. • Have information about module-pack and cell-pack designs of the battery pack.
	2.5	**At the end of this training, learners:** • Knows the structure and functions of battery management systems, • Knows the design grouping types of the electronic control unit (Master-Slave) in battery management systems. • Knows the relays/contactors and pre-charging circuits in battery management systems, • Knows the operation and types of thermal systems in battery packs.
	2.6	**At the end of this training, learners:** • Knows the operations performed throughout the life of the battery. • Knows battery transportation processes and procedures. • Knows thermal runaway, fire and precautions in batteries • Knows the waste management and procedures of batteries. • Knows the recycling processes and procedures of batteries.
	2.7	**At the end of this training, learners:** • Knows the malfunctions and error codes of batteries and systems, • Detects error codes of batteries and systems with the diagnostic device and performs maintenance and control operations.
	2.8	**At the end of this training, learners:** • Knows fuel cell electric vehicle (FCEV) technology, • Knows the properties of hydrogen, its extraction and storage, • Knows the chemical reactions, operation and types of fuel cells.
	2.9	**At the end of this training, learners:** • Knows charging modes and methods, • Knows charging connectors, • Knows the wireless charging method, • Performs electric vehicle charging.
Course Hours	40 hours	

Module Code: HEVS3
Module Title: HEVs/EVs Electric and Electronics

Course Content	**1. Basic Concepts of Electricity and Electronics** 1.1 Direct and Alternating Current Concepts 1.2. Analog and Digital Signal Concepts 1.3. Conductor, Insulator and Semiconductor Concepts 1.4. Magnetic and Electric Field Concepts 1.5. Passive Circuit Elements 1.6. Ohm's Law 1.7. Kirchhoff Law 1.8. Concepts of Power and Energy 1.9. Series and Parallel Electric Circuits 1.10. Star and Delta Connections 1.11. Measurement tools 1.12. Active Circuit Elements 1.13. Electromagnetic Interference and Noise Concepts **2. Sensors** 2.2. Angular Position and Rotation Sensors 2.3. Temperature Sensors 2.4. Pressure Sensors 2.5. Flow Sensors 2.6. Acceleration Sensors 2.7. Lambda Oxygen Sensors 2.8. Current Measurement Sensors **3. Electronic Control Systems** 3.1. Open Loop Control Systems 3.2. Closed Loop Control Systems 3.3. Microcontrollers **4. Electric Motors** 4.1. DC Motors 4.2. AC Motors **5. Rectifier, Converter and Inverters** 5.1. AC/DC Rectifiers 5.2. DC/DC Converters 5.3. DC/AC Inverters **6. Vehicle Communication Technologies-Data Buses** 6.1. Data buses 6.2. UDS protocols and services 6.3. OBD II protocols and services **7. Advanced Driving Support Systems and Autonomous Driving** 7.1. Structure and Equipment 7.2. Levels 7.3. Sensors 7.4. Sonar, Radar, Lidar, Image Detection 7.5. Positioning Systems 7.6. Driving Decision Systems

	8. Safe working, Equipment and Hazard Management 8.1. High Voltage, Dangers and Precautions 8.2. Effects of High Voltage on Human Health 8.3. High Voltage Cables and Components 8.4. Personal protective equipment 8.5. Workshop Protective Equipment 8.6. Personnel Intervention Classification	
Learning Outcomes	3.1	**At the end of this training, learners:** • Knows the basic concepts of electricity and electronics. • Recognizes and uses measuring instruments. • • Knows electromagnetic interference and propagation mechanisms.
	3.2	**At the end of this training, learners:** • Knows the working principles of sensors with different measurement capabilities used in Hybrid and Electric Vehicles (H/E).
	3.3	**At the end of this training, learners:** • Knows open and closed loop electronic control systems • Knows microcontrollers and their working principles.
	3.4	**At the end of this training, learners:** • Knows DC electric motors and their working principles. • Knows AC electric motors and their working principles.
	3.5	**At the end of this training, learners:** • Knows AC/DC Rectifier, Boost DC/DC Converter, Buck DC/DC Converter and DC/AC Inverter and their working principles.
	3.6	**At the end of this training, learners:** • Knows CAN, LIN, FLEXRAY and MOST data buses. • Knows OBD-II protocols and services. • Knows UDS protocols and services
	3.7	**At the end of this training, learners:** • Knows advanced driving support systems and their operating principles. • Knows autonomous driving systems and operating principles.
	3.8	**At the end of this training, learners:** • Knows equipment and hazard management related to safe working
Course Hours	40 Hours	

Module Code: HEVS4
Module Title: HEVs and EVs diagnostic

Course Content	**1. EV/HEV Vehicle Service Procedures** 1.1. Vehicle service acceptance procedure 1.2. Fault diagnosis, detection, reporting 1.3. Workshop Protective Equipment - signaling,- locking 1.4. Measuring Instruments and Diagnostic Devices 1.5. Technical documents (Catalogue, etc.) 1.6. EV/HEV special workshop equipment 1.7. EV/HEV fault codes (DTC) 1.8. Normal maintenance and repair 1.9. Damaged vehicle operations **2. De-electrification Procedures for EV/HEV vehicles** 2.1. Removing the power cut service socket 2.2. Locking against re-closing 2.3. Voltage measurement **3. EV/HEV electric motor fault codes and tests** 3.1. Determination of fault codes 3.2. High voltage test 3.3. ınsulation test 3.4. Equipotential equalization-Grounding test 3.5. Resistance measurement **4. EV/HEV Inverter - Converter fault codes and tests** 4.1. Determination of fault codes 4.2. High voltage test 4.3. ınsulation test 4.4. Equipotential equalization-Grounding test **5. EV/HEV Air conditioning compressor fault codes tests** 5.1. Determination of fault codes 5.2. High voltage test 5.3. ınsulation test 5.4. Equipotential equalization-Grounding test **6. EV/HEV vehicle charging system (O.B.C) fault codes and tests** 6.1. Determination of fault codes 6.2. High voltage test 6.3. ınsulation test 6.4. Equipotential equalization-Grounding test **7. EV/HEV HV cable fault codes and tests** 7.1. Continuity check 7.2. Insulation checks **8. HV Battery fault codes and tests** 8.1. Battery fault codes and tests 8.2. Battery Thermal runaway test 8.3. Module balancing 8.4. SOC, SOH, DoD parameters.

	9. Activating the High Voltage System After Repair 9.1. Installation of high voltage elements 9.2. Service socket installation 9.3. Commissioning the service battery **10. Roadside Assistance Services** 10.1. Towing Services 10.2. Emergency Response 10.3. Vehicle Fires **11. Advanced Driving Support Systems and Autonomous Driving** 11.1. ADAS Sensor Calibration 11.2. Cloud Systems and OTA	
Learning Outcomes	4.1	**At the end of this training, learners:** • Performs the service acceptance procedures of electric and hybrid vehicles. • Takes the electric and hybrid vehicle into service, applies PPE and Environmental Protective Equipment with signaling processes, and makes the vehicle safe for operation. • Knows how to use the diagnostic device • Reads high voltage systems error codes from the diagnostic device. • Knows how to read vehicle technical documents (catalogue) • Recognizes and uses measuring instruments used in low and high voltage measurement.
	4.2	**At the end of this training, learners:** • Knows and practically applies diagnostic and troubleshooting procedures on H/E vehicles. • Knows how to delete faults in ECU memory and introduce parts to ECU • Can use diagnostic devices at full capacity with their advanced functions
	4.3	**At the end of this training, learners:** • Reads electric motor fault codes • Measures high voltage • Performs insulation tests • Performs equipotential equalization-Grounding test • Measures resistance
	4.4	**At the end of this training, learners:** • Inverter-Converter fault codes with diagnostic devices • Performs Inverter-Converter tests.
	4.5	**At the end of this training, learners:** • Knows the elements of electric vehicle air conditioning system • Reads air conditioning compressor fault codes with diagnostic devices. • Performs air conditioning compressor malfunction tests.
	4.6	**At the end of this training, learners:** • Reads vehicle charging system (O.B.C) fault codes with diagnostic devices • Performs vehicle charging system (O.B.C) tests.
	4.7	**At the end of this training, learners:** • High Voltage (HV) with diagnostic devices. Diagnoses cable faults • HV. It checks the continuity of the cables. • HV. Performs insulation checks on cables
	4.8	**At the end of this training, learners:** • Reads battery fault codes with diagnostic devices • Knows the meaning of SOC, SOH, DoD parameters • Performs battery tests.

		• Knows battery thermal runaways. • Knows how to change modules • Knows the module balancing process • Knows battery leakage tests after repair
	4.9	**At the end of this training, learners:** • Activates the high voltage system after repair.
	4.10	**At the end of this training, learners:** • Knows how to transport electric vehicles with a tow truck. • Knows how to intervene in a vehicle stranded on the road. • Knows how to intervene in battery fires
	4.11	**At the end of this training, learners:** • Reads autonomous vehicle fault codes with diagnostic devices • Uses ADAS calibration device • Performs ADAS calibration
Course Hours	40 Hours	