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DEVELOPMENT AND EVALUATION OF STUDENTS' PRACTICE SKILLS IN VOCATIONAL AND TECHNICAL EDUCATION OF ELECTRIC VEHICLES

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Abstract: Rapid technological advances and population growth are causing global energy shortages and environmental problems. All countries in the world are making great efforts to develop energy-saving vehicles, especially focusing on the production of environmentally friendly vehicles that run on electric energy. In the very near future, there will be a shortage of qualified personnel in the field of battery electric vehicle (BEV) failure diagnosis, maintenance and repair, electric vehicle production, and after-sales services, which will be one of the leading professions in the global trend. This study was conducted to evaluate the practical skills of individuals studying in Karaman province within the scope of training the qualified personnel needed by the sector in the field of maintenance and design in the field of electric vehicle technologies. The individuals underwent skills tests based on 10 application skill criteria, encompassing a total of 112 subtasks. The tests revealed that 81% of the participants possessed general application skills and exhibited the characteristics of EV technical personnel. It has been determined that adequate vocational and technical training has been provided to meet the personnel demand in the field, aligned with the projected widespread use of EVs soon.

Keywords: Electric vehicle, Diagnosis, Fault, Maintenance, Vocational and technical education

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1. Introduction

In parallel with the rapid increase in the global population and technological advances, there has been a significant rise in the number of vehicles being used by people. One of the major contributors to global climate change is the emission of exhaust and non-exhaust pollutants from fossil fuel-powered internal combustion engines. Pollutants such as CH, CO, NO_x, and particulate matter (PM) are released into the atmosphere and have detrimental effects on the environment (Güney and Küçüksarıyıldız, 2019; Güney and Aladağ, 2020; Güney and Öz, 2020a; Güney and Öz., 2020b; Güney and Aladağ, 2021; Güney and Aladağ, 2022; Shang et al., 2024). At the forefront of efforts to address air pollution and global warming is the promotion of vehicles that utilize electrical energy to power their mechanical systems. Among the various types of alternative vehicles studied, battery-powered electric vehicles (BEVs) have received significant attention. BEVs are considered a promising solution to reduce dependence on fossil fuels and mitigate pollution arising from the transportation sector. These vehicles rely on battery technology to store electrical energy and provide a cleaner and more sustainable mode of transportation (Alves et al., 2016). Because the energy used in EVs can be obtained from renewable energy sources such as wind, solar, and hydroelectricity (Ajanovic and Haas, 2016). In addition to the outstanding performance features of these vehicles, such as zero exhaust emissions, low noise pollution, and high energy efficiency, their clean energy consumption is attractive (Güney and Kılıç, 2020). Also, thanks to government initiatives and technological advances, interest in BEVs continues to increase worldwide.

BEVs are similar to internal combustion engines (ICE) in terms of basic technology. However, there are missing or excess systems in BEVs. For example, while the fuel combustion system, fuel tank, and combustion system are not available, there are systems connected to electrical energy such as traction batteries. The main components of an BEV are; the electric traction motor, transmission, multimedia system, electronic engine computer (EVC), traction battery, auxiliary battery, battery management system (BMS), smart battery charger, AC/DC-DC/AC converter, charger, high voltage, and low voltage wiring system, braking system, regenerative braking system (RBS), vehicle body, chassis/body system, thermal cooling and lubrication systems (Dhameja, 2001). These components, particularly those specific to BEVs, are described below.

1.1. Electric Traction Motor

It is the rotor/stator component that converts electrical energy into mechanical energy or mechanical energy into electrical energy and works with classical electrical principles. It is controlled by the electronic engine computer (EVC). EVC regulates the amount of current and voltage that the electric motor receives (Jouda et al., 2024). These motors are of two types, either the motor that uses the direct current (DC) in the traction battery as DC directly or the motor that uses it by converting it to alternating current (AC). The accelerator pedal generates the appropriate torque by sending a signal to the controller that adjusts the speed of the vehicle by changing the frequency of the current power from the inverter to the motor. Operating voltages can be 360 V or higher. The controller receives a signal from the vehicle's accelerator pedal and controls the electrical energy supplied to the engine, causing torque to turn the wheels. In the past, DC motors were widely used for variable-speed applications. However, with technological advances in electronics, AC motors are now more widely used for these applications. DC motors are generally easier and cheaper to control, but they are usually larger and heavier than AC motors. At the same time, AC motors and controllers often have higher efficiency at very different operating parameters. Today, both AC and DC technologies are used in commercial cars (Dhameja, 2001). It drives the wheels of the vehicle with the help of gears in the electric transmission. Some vehicles use motor generators that perform both driving and regeneration functions. In these vehicles, when the brake is applied or the vehicle is slowing down, the motor becomes a generator and produces regenerative energy and sends it back to the traction battery.

1.2. Charger Unit

It is the part that mediates the vehicle to provide energy input by connecting to an external power source in order to charge the traction battery.

1.3. DC/DC Converter

The direct current (DC) voltage taken from the external electricity network is stored in the traction battery by converting the voltage too high voltage by means of the charger. It also converts the high voltage stored in the traction battery to low DC voltage to power the vehicle accessories and recharge the auxiliary battery.

1.4. Charger

Via the AC to DC converter in the charger, it takes the supplied AC electricity and converts it to DC voltage to charge the traction battery. It also communicates with the charging equipment and monitors the traction battery's state of charge (such as current, temperature, and voltage characteristics). The charger has single-phase or 3-phase residual current relays and induction coils to prevent undesirable situations such as leakage current and electrification, and to obtain clean and undisturbed current.

1.5. Electronic Power Control Unit

It is the unit that manages the electrical energy coming from the traction battery to control the speed of the electric traction motor and the torque it produces.

1.6. Thermal System (Cooling)

This system is an electronic processor equipped with sensors to manage and control the proper operating temperatures of the engine, electric motor, power electronics, and other components. Liquid-based thermal management systems are generally preferred over BEVs, where cold plates are used to circulate the coolant more efficiently (Kalkan et al., 2022).

1.7. Traction Battery

A traction battery is a high-voltage element that can store the energy required to move the vehicle. Traction batteries are generally produced with a weight of 200 – 400 kg, a working capacity of 20-100 kWh, and a voltage of 100-600 volts. By combining multiple modules, the total traction battery capacity is created. Modules; It is produced with technologies consisting of cells such as Iron-Nickel, Lead-Acid, Nickel-Cadmium, Lithium-Polymer, Sodium-Sulphur, Aluminium-Silver and Zinc-Silver, Aluminium-Air, and Zinc-Air (Hamurcu et al., 2021; Malozyomov et al., 2024). Among these batteries produced for use in EVs, Lithium-Ion batteries are mostly preferred due to their performance features such as high voltage, energy density, and long life (Zenk and Ertuğral, 2021).

Each module is enclosed in a metal frame insulated with spacers and connected in series to each other in a sequential manner. The current consisting of the combination of the modules is transmitted to the electric motor by the power circuit. Since the power circuit has a high-voltage capacity, it is insulated and secured. In addition, high-voltage voltage is controlled with energy-cut safety interlocks. It is mounted on vehicles in robust enclosure cabinets. The charging time, discharge rate, charge/discharge frequency, charge, and discharge temperature usage modes of the batteries are the main factors affecting the efficiency of environmental conditions. Regenerative braking systems (Güney and Kılıç, 2020) can increase the driving range of EVs by around 25%.

1.8. Auxiliary Battery

Elements in an electrically driven vehicle that provides low-voltage electricity to power vehicle accessories.

1.9. The Electronic Engine Computer (EVC)

It is programmed to communicate with all components by managing all driving and usage phases starting from charging the vehicle. It controls the functions of the components. For example; speed, pedal pressure, airbag, wiper, tire pressure, etc. It is a complex multimedia system that enables the management of the vehicle by communicating with more than 100 sensors. Also, on each traction battery; there is an electronic electronic management system (BMS) to control data such as charge status, module/cell voltage, cell temperature, and fault status. This system is used by integrating into the EVC.

1.10. Electro-Mechanical Transmission

It is an electro-mechanical gear mechanism that moves the wheels by converting the electrical power at different speeds and torques coming from the electric traction motor into mechanical power. Smooth and consistent gear changes are achieved through this electro-mechanical system. It has vibration damping, acoustic comfort, and high-strength properties.

In the general physical structure of the system, unlike the ICE, there are low-speed input motors, clutches, planetary gear, and a powerful motor and physical powertrain. Clutches work like friction plate electromagnetic brakes. A spring keeps the plates apart until the electromagnet is activated, which magnetizes the floating plate and brings the braking surface into contact (Beaudoin and Boulet, 2022). The load motor provides the driving or braking torque to the wheels by generating the torque expected by the powertrain via the electromechanical system. The input motor can accompany the load motor if necessary (He et al., 2022).

1.11. Regenerative Braking System

By integrating an electric motor into the RBS front and rear wheels, many advantages can be gained from the system over conventional vehicles. First, the additional torque coupling mechanism can be eliminated. Second, when the required torque is relatively large, all-wheel drive can be applied. Finally, during the deceleration process, the electric motor can be used as a generator by applying regenerative braking (Lv et al., 2015), thus providing energy economy with recovery from regenerative braking (Lv et al., 2017). This electrical energy is then stored in energy storage systems (e.g. batteries or ultra-capacitors) and used as a drive for electric motors as needed. Regenerative and mechanical braking systems must be fully integrated to ensure the reliable and effective operation of regenerative braking. To meet the driver's demand, this integration requires smooth and accurate control of combined regenerative and mechanical braking (Setiawan et al., 2019). Therefore, a harmonious operation between the hydraulic braking system and the regenerative braking system is an important element in the design of the EV brake control strategy (Peng et al., 2008).

In EVs, hydraulic oil is used in the brake and power steering systems, coolants are used in the engines and electronic control modules, coolants and lubricants are used in the air conditioning compressors, and oils are used in the engine of the driveline, differential, and transmission. Low-freezing antifreeze coolants are used to cool the engine, control unit, and battery pack. In most cases, these lubricants and coolants are the same as those used in ICE. EVs do not store large volumes of flammable liquids. Usually, electrical devices are used to heat or cool the passenger compartment (Dhameja, 2001).

In the absence of expert technical personnel on the traction battery and high-voltage line, no action should be taken. For this reason, high-voltage cables and components are used in orange-colored reinforcements. Maintenance work on the traction battery requires the use of personal protective equipment and the use of safety precautions such as the correct use of technical knowledge. Therefore, every operation to be carried out on the traction battery should be carried out by persons with technical equipment. Any voltage higher than the voltage at the auxiliary battery connection is considered high voltage.

As a customer feature in reverse, the motor torque and speed are limited by the EVC computer. If the EVC computer didn't limit performance, the reverse would have just as much speed and torque as the forward. Its reverse gear is activated by reversing the fed phases. The electric motor rotor and reduction box are connected to a gear assembly. There is no special gear for reverse movement.

In this training model, individuals studying in the field should receive training on both theoretical and real tools by using all the possibilities of technology. In this way, the human resources needed by the industry will be trained and socio-economic development will be achieved. With the inclusion of new-generation vocational education trends in the education system, it will be possible to increase the technological literacy level of individuals, improve their ability to use new technologies, and can solve the problems they will encounter in the future.

The main reason why we focus on education in the field of electric vehicle repair, maintenance and repair, which will be one of the leading professions of the global trend, is to seek a solution to the personnel gap that will arise in electric vehicle production and after-sales services as qualified technical staff of individuals who will be trained in this field. Very soon there will be a large number of new professions for electric vehicle maintenance in the world. In this technological transformation, some professions will become obsolete, but with the right model, the workforce will be able to switch to new business lines. For example, carburetor, spark plug, or exhaust experts can become battery experts in a short time.

The technological progress of countries, their economic and social development, and their competitiveness at the global level is closely related to their success in vocational and technical education. All scientists, industrial experts, and professionals agree that vocational and technical education is the secret behind the technological progress and economic strength of developed countries around the world (Dangote, 2013).

The main purpose of gaining the ability to practice on the real tool is to increase the students' performance as it reveals the assessment areas to the students. This improvement reduces the waste of resources such as time, effort, and money by educating students with the right knowledge and skills, which in turn produces students with the right knowledge and skills desired. In order to assess these skills, it is necessary to develop a document containing the design of the assessment tool, namely assessment parameters that can be used to evaluate the performance of the student's practical task activities. In addition, the reliability and validity of this technique are possible with the development of training modules that will determine the criteria for practical skills in the new field.

The quality of learning skills that an education program provides to students is evaluated by the extent to which the objectives of technological knowledge or practical skill acquisition are achieved (Okwelle, 2012). The greater the effectiveness and efficiency with which individuals can apply the learned skills at the end of a course or study program, the more successful the acquired skill will be (Hager et al., 1994). In the field of vocational and technical education, technological teaching and practical application form an important part of the activities of developing applied skills.

On-the-job training in vocational and technical education that prepares the individual for the real work environment in an organized and coordinated way can be described as a process with its physical, mental, emotional, social, economic, and personal aspects by gaining the knowledge, skills, attitudes, and professional habits required for a profession that is necessary for the maintenance of individual and social life (Alkan et al, 2001; Özkan, 2021; Kong et al., 2024). Therefore, assessing skill test subjects by practical application rather than answering questions (Kong et al., 2024) is considered by most to be a more reliable technique. Performance criteria require students to apply the practical skills and operations taught and to perform adequately in conditions similar to industrial working conditions (Igaru, 2023).

Educational institutions providing vocational and technical education in Türkiye offer training at different levels with apprenticeship, technician, and engineering programs to train qualified manpower in line with the current global developments needed for the economic and technological development of the country. Applied sciences operate to train professionally educated manpower who has acquired minimum knowledge and skills in the scientific and industrial fields to ensure commercial and economic development. Personnel studying in this field participates in real business life by completing the modules of basic technology and application skills required by the program they are studying.

The method used for successful teaching and learning is of interest to educators because teaching methods play an important role in stimulating students' creative and critical thinking by persuading students to look at an event or problem from many angles as a team (Eison, 2010). These can only be achieved when an appropriate teaching method is applied.

Students' skills testing methods may be in the form of process management and the ability to do the implementation activity correctly, or a combination of both (Moses et al., 2017). Process management includes the evaluation of student performance with careful and consistent instructor observation. The skill of the application activity is evaluated by whether the student correctly applies the parameters in the defined work module. This means that the skills test includes evaluating how students are doing as well as the task or product completed. Both process and application skills are performed by the trainer using checklist tables to be used to rate students' performance.

In line with the work done in the areas of global climate change, clean air and energy-saving, activities related to electric vehicles have gained great momentum all over the world. With the inclusion of new-generation vocational education trends in the education system, students will be able to increase their technological literacy level, improve their ability to use new technologies, and can solve the problems they will encounter in the future. The many complex subsystems of today's electric cars are extremely demanding to maintain and therefore require experienced expertise. These systems require regular inspection, maintenance and repair. For this reason, it is necessary first to take a long theoretical training for the technical personnel who will work on electric vehicles to specialize in the details of EVs. Afterwards, they should be equipped with knowledge, skills, and experience through applied training. In terms of safety and comfort, customers expect the motor vehicle technician to diagnose, maintain and fully repair any malfunction in the car. This study was carried out to contribute to the training of qualified personnel needed by the industry in the field of electric vehicles, which is expected to be one of the technologies of the future. In the study, the practical skills of the students who received sufficient theoretical education in Karaman/Türkiye were evaluated. For this purpose, evaluation parameters of the training modules have been determined to test student experiences. Students' success rates were calculated according to these parameters.

2. Materials and Methods

2.1. Design, Area and Population of the Study

Figure 1 illustrates the flowchart of the processes outlined in the study plan. Figure 2 illustrates image of the electric vehicle under application. Practical skills tests were conducted on 14 individuals who are studying in the field of electric vehicles in Karaman/Türkiye. These individuals have received comprehensive theoretical knowledge in the field of electric vehicles throughout their education. The assessment of their practical skills was based on a set of parameters developed for the failure, diagnosis, maintenance, and repair of electric vehicle components. The practical skills assessment was performed on a fully electric passenger car located in Karaman/Türkiye, and its specifications are provided in Table 1. In instances where individuals made errors in specific skill steps, the trainer provided corrections, and the remaining sub-tasks were completed. Maintenance and repair of electric vehicles are generally the same as maintenance of ICEs, with notable exceptions such as the traction battery, electro-mechanical transmission, regenerative braking, and auxiliary systems. In the design of BEVs, basic components such as chassis, braking, lighting, bodywork, steering system, suspension, and undercarriage are the same as ICEs.

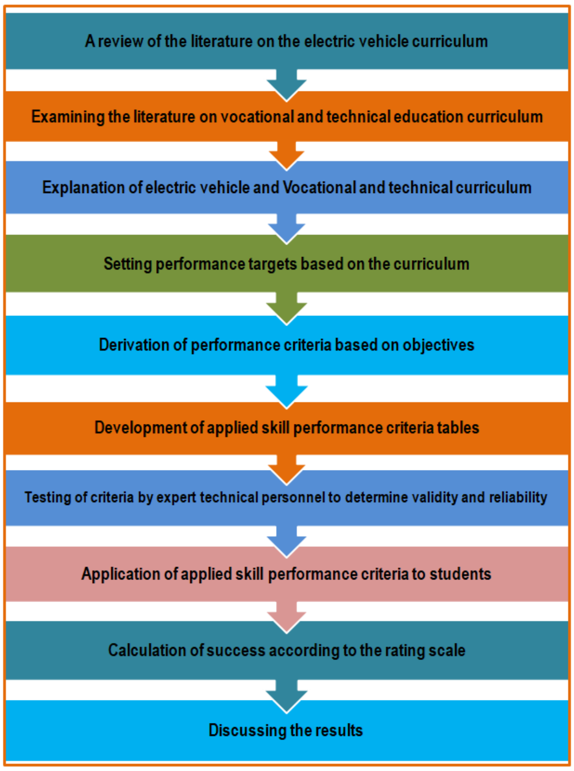

Figure 1. Flow chart showing the working methodology.

Figure 2. Image of the electric vehicle under application.

Table 1. Application car technical specifications

Car features	
Motor type	Electric
Motor power	68 kW
Maximum speed	135 km/h
Torque	226 Nm
Range	185 Km
Traction battery capacity	22kWh
Traction battery voltage	398v
Traction battery type	Lithium-ion
Transmission	Automatic
Weight	1605kg
Model year	2012

2. 2. Data Collection and Method of Data Analysis

The prerequisite of the study was determined to complete the compulsory field courses of the automotive program. For the study, application skill control parameters in BEV automotive breakdown, diagnosis, maintenance, and repair were determined. The determined parameters were applied by expert technical personnel before testing on the individual. Afterwards, it was applied to each person separately. The total skill assessment was calculated based on the percentages of making the application skills correct.

Customers expect the optimal combination of the growing popularity of electric vehicles, environmental friendliness, comfort, excellent technical and operational characteristics, and low maintenance costs to be consistently provided. They desire their needs to be met without any dissatisfaction in the event of any malfunction. However, with the rapid expansion of the market share in this sector, it is crucial to have qualified technical staff equipped with the necessary technical expertise to quickly respond to the demands. Another expectation is for fast, reliable, and cost-effective vehicle transactions.

Individuals who will be technical personnel for electrical vehicle breakdown, diagnosis, maintenance and repair should have gained the expected personal characteristics expected from them and the minimum level of technical knowledge. In other words, for a failed electric vehicle to be prepared for safe use again, it is expected to be an expert on the technical details of its components and parts. To summarize these requirements, Table 2 presents the criteria for technical knowledge, skills, and their corresponding subtasks for individuals aspiring to become specialists in electric vehicle fault diagnosis, maintenance, and repair. This table outlines the specific qualifications and competencies necessary for these professionals in order to effectively carry out their roles in the field.

Table 2. Ability to conform to the general characteristics of individuals who will be electric vehicle breakdown, diagnosis, maintenance, and repair specialists

N	Practice name	NPPC	CPP
1	Knowing and applying general occupational health and safety rules	13	0.93
2	Know and practice the use of personal protective equipment and equipment to make the vehicle safe for any operation on the components of an electric vehicle.	13	0.93
3	Meticulously following all necessary instructions from the very beginning	12	0.86
4	Carry out an external inspection of the vehicle	13	0.93
5	Controlling warning and lighting systems	12	0.86
6	To be able to perform the traction battery deactivation procedure	12	0.86
7	To know about general motor vehicles, mechanics, transmission groups, bodywork, and undercarriage	12	0.86
8	General knowledge of auto electrical and electronics	13	0.93
9	Absence of any health or mental condition that may pose a danger to the specialist while working on an electric motor vehicle	13	0.93
10	To have the knowledge of authorization and maintenance and safety information to be applied while operating on an electric vehicle.	13	0.93
11	Have professional training to perform electrical work such as removing a traction battery or diagnosing a traction battery chain component	14	1.00
Average application skill rate			0.91

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

According to the 11 sub-assessment criteria in Table 2 above, in terms of the general characteristics of the participants, the percentage of eligibility criteria was determined as 91%. The participants correctly applied the sub-tasks of the skill rating criteria "Ability to know the factors affecting the performance of the electric vehicle" in Table 3.

According to the 8 sub-assessment criteria in Table 3 above, in terms of the "Ability to know the factors affecting the performance of the electric vehicle" application skill, the correctness level was determined as 85%. The participants who correctly applied the sub-tasks of the skill rating criteria of "Ability to recognize and maintain the regenerative braking system" were identified in Table 4.

According to 9 sub-assessment criteria in Table 4 above, in terms of application skill, “Ability to recognize and maintain the regenerative braking system”, the correctness level was determined as 69%. The participants who correctly applied the sub-tasks of the skill rating criteria of "Ability to Adjust Contact Breakers" were identified in Table 5.

According to the 13 sub-assessment criteria in Table 5 above, in terms of the "Ability to Adjust Contact Breakers" application skill, the correctness percentage was determined as 76%. The participants correctly applied the sub-tasks of the skill rating criteria of "Ability to charge auxiliary battery" as in Table 6.

Table 3. Ability to know the factors affecting the performance of the electric vehicle

N	Practice name	NPPC	CPP
1	Preliminary training in securing an electric vehicle and intervening in all parts of the vehicle	14	1.00
2	Maintenance of mechanical parts	12	0.86
3	Checking the multimedia system and checking that its integration is working properly	10	0.71
4	Checking the climatic conditions of the driving environment	12	0.86
5	Checking the driving road conditions	13	0.93
6	Checking the driving road conditions	14	1.00
7	Driver's driving style	10	0.71
8	Checking the topography of the driving environment	10	0.71
Average application skill rate			0.85

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

Table 4. Ability to recognize and maintain the regenerative braking system

N	Practice name	NPPC	CPP
1	Knowing and maintaining the regenerative braking system in addition to hydraulic braking	11	0.79
2	Checking the braking force distribution between the separated pedal braking system computer, electric motor, and hydraulic braking. Checking the maximum amount of energy recovered.	10	0.71
3	Checking whether the auxiliary battery is periodically replaced according to the electric vehicle maintenance schedule	13	0.93
4	Getting to know the electric brake system and hydraulic brake system	10	0.71
5	Checking whether the dedicated pedal braking system, which analyzes the driver's needs, simulates the classic brake pedal feel, replenishes the braking pressure, manages and distributes the braking between the electric motor and the hydraulic receiving cylinders, is performing these tasks	10	0.71
6	Checking the vehicle stability, the limits of the powertrain, additional safety mechanisms such as ABS, ESC, and the distribution of resistive torque based on comfort mechanisms controlled by the dedicated braking computer	9	0.64
7	Checking whether the computer is optimizing the braking distribution using the driving parameters and the traction battery level	8	0.57
8	According to the state of charge of the traction battery; checking whether it operates electric braking or hydraulic braking mechanisms.	8	0.57
9	Controlling the intelligent braking mechanism of the separated pedal braking system.	8	0.57
Average application skill rate			0.69

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

Table 5. Ability to adjust contact breakers

N	Practice name	NPPC	CPP
1	Putting the vehicle in neutral	14	1,00
2	Finding the distributor and opening the cap of the contact breaker	10	0.71
3	Unclip the fasteners and carefully place the cap in position next to the dispenser	10	0.71
4	Removal of the rotor, noting its position and method of insertion	10	0.71
5	Carefully turning the motor by hand with the help of the motor pulley until the dots are at the widest opening	10	0.71
7	Examination of contact breaking points in terms of wear conditions	10	0.71
8	Checking the condition of the mechanical advance and retard weights by removing the distributor base plate. Checking whether the weights move freely and the holding springs are in place and intact	10	0.71
9	Checking vacuum advancing and retarding units	10	0.71
10	Locating contact breaker points, installing and replacing the setscrew	10	0.71
11	Use of the appropriate gauge to check the general condition of the dispenser	10	0.71
12	Restarting the system	10	0.71
13	Putting the vehicle in neutral	14	1.00
Average application skill rate			0.76

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

Table 6. Ability to charge the auxiliary battery

N	Practice name	NPPC	CPP
1	Cleaning the battery box and terminals	14	1.00
2	Opening the ventilation flaps	14	1.00
3	Checking electrolyte levels and adding enough distilled water	10	0.71
4	Determination of charge rate and time	13	0.93
5	Make sure the charge timer and the main switch are off	13	0.93
6	Connecting the negative charge cable to the negative terminal and the positive charge cable to the positive terminal	13	0.93
7	Plugging the charger's power cord into a power outlet	14	1.00
8	Adjusting the charger voltage switch to the appropriate battery voltage and then delivering energy to the battery	10	0.71
9	Adjusting the charging time of the battery with the timer	11	0.79
10	Current control to obtain the appropriate charge rate	11	0.79
11	Turning off the charger to test the battery	10	0.71
12	Checking that the battery is sufficiently charged and reconnecting to the vehicle	10	0.71
13	Checking if the vehicle is working properly	13	0.93
Average application skill rate			0.86

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

In Table 6 above, in terms of the "Ability to charge auxiliary battery" application skill, the percentage of correctness was determined as 86% according to 13 sub-evaluation criteria. The participants correctly applied the sub-tasks of the skill rating criteria of "Ability to battery maintenance and leak testing" as shown in Table 7.

In Table 7 above, in terms of applying "Battery maintenance and leak test skills", the percentage of correctness was determined as 80% according to 7 sub-assessments. The participants who correctly applied the sub-tasks of the skill rating criteria of “Ability to fault check and replace bulbs " are in Table 8.

According to the 9 sub-assessment criteria in Table 8, “Ability to fault check and replace bulbs” application skill, the correctness percentage was determined as 85%. The participants who correctly applied the sub-tasks of the skill rating criteria of “Ability to control the cooling unit” were identified in Table 9.

In Table 9 above, in terms of the "Ability to control the cooling unit" application skill, the percentage of correctness was determined as 70% according to 10 sub-assessment criteria. The participants who correctly applied the sub-tasks of "Ability to traction battery maintenance" skill rating criteria were identified in Table 10.

According to the 25 sub-assessment criteria in Table 10, “Ability to traction battery maintenance” application skill above, the correctness percentage was determined as 78%. The participants correctly applied the sub-tasks of the skill rating criteria of "Ability to control in-car comfort accessories" as in Table 11.

According to the 8 sub-assessment criteria in Table 11 above, in terms of the "Ability to control in-car comfort accessories" application skill, the accuracy rate was determined as 87%.

Table 7. Ability to battery maintenance and leak testing

N	Practice name	NPPC	CPP
1	Getting a voltmeter	13	0.93
2	Disconnecting the negative battery cable before the positive cable	13	0.93
3	Connecting the negative voltmeter wire to the battery terminal	9	0.64
4	Placing and touching the positive voltmeter wire at various points on the top and side of the battery	11	0.79
5	Reading and confirming the voltage on the voltmeter	10	0.71
6	Clean the battery and battery cable with cleaner	9	0.64
7	Disconnecting the negative battery cable	13	0.93
Average application skill rate			0.80

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

Table 8. Ability to fault check and replace bulbs

N	Practice name	NPPC	CPP
1	Disconnecting the electrical connections on the back of the bulb by pinching to release the connector	10	0.71
2	Removing the protective rubber cap	13	0.93
3	Removing the bulb by freeing it from the clip holding it in place	10	0.71
5	Correct installation of the new bulb	12	0.86
6	Attaching the bulb to the sockets of the energy cables	12	0.86
7	Checking the protective cap, replacing it with a new one if necessary	13	0.93
8	Energizing the bulb to test	13	0.93
Average application skill rate (%)			0.85

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

Table 9. Ability to control the cooling unit

N	Practice name	NPPC	CPP
1	Checking the coolant flow	14	1.00
2	Knowing and controlling the functions of the coolant pump at temperatures below 50 °C and above 50 °C	8	0.57
3	Knowing the temperature limit values of the components when the coolant flow rate reaches its maximum	8	0.57
4	Knowing the speed limits of the cooling unit depending on the vehicle’s characteristics	8	0.57
5	Knowing and controlling the functions of the relays and the resistor unit in the refrigeration unit	8	0.57
6	Controlling the cooling pump, which is controlled by the EVC computer and works while driving	9	0.64
7	Checking the cooling level of the motor transmission group	9	0.64
8	Checking the fan group operation and activation temperature	10	0.71
9	Checking if the coolant is passing through the charge pump	11	0.79
10	Controlling the activation of the fan while driving, depending on various factors (such as vehicle speed, temperature rise, motor temperature, outside temperature, motor operating conditions, and current level)	13	0.93
Average application skill rate			0.70

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

Table 10. Ability to traction battery maintenance

N	Practice name	NPPC	CPP
1	Before all operations on the traction battery, the vehicle must be safely stopped, and the ignition switched off	14	1.00
2	Knowing the meanings of the electric vehicle dashboard	10	0.71
3	Locking each power cable with a high voltage interlock suitable for electrical disconnection	9	0.64
4	Controlling the ambient temperature (such as interior and exterior temperature, motor temperature, pressure sensors, motor cooling fan zone, instrument panel, multimedia system sensors, valves, and gauges)	10	0.71
5	Recognition of socket types, power supply of sockets, knowing the highest current and highest voltage values	9	0.64
6	Knowing the charging times of the battery according to the socket modes	9	0.64
7	Charging and checking the battery in domestic socket mode	13	0.93
8	Charging the battery in socket mode on the special terminal with the mobile cable or the cable integrated into the terminal	10	0.71
9	Charging the battery in DC station mode with the cable integrated into the terminal	12	0.86
10	Knowing the meanings of the warning signs and rectifying the resulting faults to check whether they are working properly while the vehicle is being started	11	0.79
11	Checking whether the safety relays in the EVC computer are activated when the charging cable is connected to the electrical socket	10	0.71
12	Checking whether the voltage from the charger is charged to the battery module via the positive and negative poles	11	0.79
13	Detection of whether the charging process of each module is controlled by the battery computer	10	0.71
14	Knowing the measurement of high voltage and leakages with	10	0.71
15	Performing all tests with “VOLTAGE-FREE” power disconnected	9	0.64
16	Making sure that the electrical load of the circuit is discharged and checking it with a voltmeter	10	0.71
17	DC voltages can be high, so limit personnel access and use personal protective equipment	9	0.64
18	Ensuring that the electrical load of the circuit is discharged by applying appropriate procedures (such as short circuit or earthing)	9	0.64
19	Disconnecting the negative battery cable from the positive cable before	13	0.93
20	Connecting the negative voltmeter wire to the battery terminal	13	0.93
21	Placing the positive voltmeter cable at various points on the top and side of the battery and checking the energy	12	0.86
22	Checking and confirming the voltage value on the voltmeter	14	1.00
23	If an incorrect value is read, clean the battery, battery cable ends, and battery connections with cleaner, baking soda, or water	13	0.93
24	Supplying electricity to the power cables by unlocking the high voltage of the charging battery	9	0.64
25	Checking whether the vehicle motor is running	13	0.93
Average application skill rate			0.78

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

Table 11. Ability to control in-car comfort accessories

N	Practice name	NPPC	CPP
1	Controlling warning and lighting systems	13	0.93
2	Knowing and checking the meaning of the signs on the instrument panel	13	0.93
3	Checking the alignment of the car steering wheel and mirrors	13	0.93
4	Checking the airbag systems	12	0.86
5	Checking air conditioner systems	11	0.79
6	Controlling sound and broadcast systems	11	0.79
7	Controlling drive and mechanical systems	12	0.86
8	Checking window, door, and hood systems	12	0.86
Average application skill rate			0.87

NPPC= number of persons who practice correctly, CPP= correct practice percentage.

3. Results and Discussion

In parallel with the rapid increase in electric vehicles in the world, the need for professionals who can design, malfunction, diagnose, maintain, repair and sell in this field also increases. Maintenance of electric vehicles is very practical and less than that of internal combustion engine vehicles. For example, there are no extra tasks in electric vehicles such as maintenance and repair of spark plugs, exhaust lines, and carburetors in internal combustion engines. However, for the vehicle to be used safely for a long time, its maintenance must be done on time and by expert personnel. In the field of electric vehicles, especially traction batteries, electro-mechanical transmissions and the technologies of the elements connected to them are new, so they differ from traditional vehicle maintenance. In addition, it is necessary to be careful as there is high voltage electrical energy in the vehicle. Practice skills tests were carried out to ensure that the professional personnel who will respond to the expectations of the customers quickly take charge in the field. The skill performance averages of these tests are presented in Table 12. According to the test results, the performance of "compliance with the adjust contact breakers" was the highest with a value of 92%. The lowest skill performance was obtained in the application skills "battery maintenance and leak testing" with a value of 69%. Students' general practice ability was accepted as a good level with a grade 82%.

EV specialist: It is the technical staff who can successfully perform the above-mentioned application skills and sub-tasks specific to the vehicle. It was thought that the good result of the application skill assessment with a value of 85% was due to the fact that the majority of students had previously received education in the field of vocational and technical education and areas similar to EV education. In addition, it was observed during their theoretical education that the general tendencies of the individuals were prone to practical skills. In light of the data obtained, during the vehicle maintenance process of the students who were trained, it can be accepted that they are capable of performing the external inspection of the warning, lighting, brake, cooling, lighting, comfort, traction battery, auxiliary battery, accessory and driving kit systems for malfunction, diagnosis, maintenance, and repair.

Table 12. The rate of students' general practice ability

N	Practice name	Average practice skill rate
1	Ability to conform to the general characteristics of individuals who will be electric vehicle breakdown, diagnosis, maintenance, and repair specialists	0.91
2	Ability to know the factors affecting the performance of the electric vehicle	0.85
3	Ability to recognize and maintain the regenerative braking system	0.69
4	Ability to Adjust contact breakers	0.76
5	Ability to charge an auxiliary battery	0.86
6	Ability to battery maintenance and leak testing	0.80
7	Ability to fault check and replace bulbs	0.85
8	Ability to control the cooling unit	0.70
9	Ability to traction battery maintenance	0.75
10	Ability to control in-car comfort accessories	0.87
The rate of students' general practice ability		0.81

4. Conclusions

The electric vehicle industry is growing rapidly due to many issues such as energy scarcity, environmental problems and high costs. The aim of this study is to evaluate the practical application skills of individuals regarding electric vehicles in Karaman/Türkiye. The primary goal was to prepare and equip qualified personnel for the future of electric vehicles, recognizing their importance as an important technology in the coming years. In the tests conducted according to 10 application skill criteria and 112 sub-task definitions, it was determined that 81% of the individuals had the characteristics of an EV technical staff with good general application skills. In the upcoming period, it has been revealed that sufficient vocational and technical training is provided to meet the personnel demand that will occur in the field in parallel with the spread of EVs.

Author Contributions

The percentage of the author(s) contributions is presented below. The author reviewed and approved the final version of the manuscript.

	B.G.
C	100
D	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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