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# Implementation of Blended Learning Approach for Tertiary Level Training on Vehicle Electrification

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## ABSTRACT

This paper focuses on the development of a short training curriculum for tertiary level education that can horizontally cover the Electric Vehicle technology in a manner understandable and attractive to students of appropriate background. The training program is divided into four groups of technical topics, the extend of which is balanced with regards to the learning outcomes and the teaching time provided. The blended teaching nature is supported by theoretical online lectures, synchronous and asynchronous, a great number of laboratory courses to enhance knowledge assimilation and a medium size project divided into two parts for the students to delve into the engineering way of thinking through a problem based learning approach. In the first part, the students exploited the Augmented Reality technology in order to describe the electric powertrain of small scale electric vehicles after having troubleshooting them. Their work and findings were utilized for the preparation of a scientific paper in the second part of the project. The training program was completed by a short industrial internship. The transferability of the training program is discussed in the last section of the paper.

**Keywords:** electric vehicles, electric vehicle technology, vehicle electrification, training, curriculum development, high voltage batteries, electric powertrain.

## INTRODUCTION

The global interest in electric vehicles (EVs) has been tremendously increased during the past decade and it is expecting to continue increasing at an exponential rate [1]. A brand new technology spreads all over the automotive sector and creates needs that a few years ago nobody expected to be that important. EV charging infrastructure, high-voltage batteries, regenerative braking are meanings that are considered self-evident and not exotic as was happening not more than 15 years ago [2, 3]. The sudden entry of the so-called vehicle electrification in everyday life activities has also caused the need for a corresponding training of practically all people, i.e. automotive professionals, scientists, even vehicle drivers that must be adopted to new driving environment. From the simple battery charging, which unfortunately is not as simple or in-innocent as a refuelling of a conventional gasoline or diesel vehicle, to the high voltage battery that suddenly becomes the most crucial and expensive part of a vehicle instead of the traditional internal combustion engine (ICE), and from the silent and without emissions electric motor to the orange and dangerous high voltage circuit, everything appears to be new and strange for the one that grew up with the noisy and polluting ICE and its lubricants. The EV incorporates a brutal entry of the electrical engineering energy technology to the traditional mechanical application of the vehicle [4–6].

From the automotive professional mechanic point of view the change is vast, the shortage in experienced personnel equally significant and it must be covered as soon as possible [7–9]. As the bases have been set from various training entities, i.e. Universities, Institutes, training centres aligned with professional associations, it is just a matter of time for the automotive sector to come into balance. Many EV technology training courses have appeared, the great majority offered online through massive open online courses (MOOCs) platforms, promising knowledge assimilation and certification. Of course, in this scientific field and especially for automotive mechanics, the ultimate certification requires focused laboratorial experience as well. Various educational oriented projects can be found under the umbrella of the Institute of the Motor Industry (IMI) [10] or the Automotive Skills Association (ASA) [11] that connect training to skill requirements by the industry and focus on specific sector of the EV technology (batteries [12], cyber security [13] etc.), or offer full certification [14]. Again, the problem remains, grows and market needs are not fully met.

On the other hand, scientific training in the tertiary level education has other characteristics and challenges. The multidisciplinary nature of the EV subject is quite difficult to form a dedicated undergraduate curriculum and can be offered as a direction or a single course of electrical, mechanical or automotive engineering curricula. As far as postgraduate courses concern, there are several programs dedicated on EV technology around Europe [15, 16], mostly in the UK [17–19], but still it appears to be much easier to include a few related courses in an already existing, automotive oriented, postgraduate curriculum. Certainly, the incorporation of laboratory courses and practical training into any EV course is of significant importance. Some other of the initiatives taken to promote EV technology mainly focus on research around EVs and not training, like projects of the European Association for Electromobility (AVERE) [20].

This paper presents the development and piloting deployment a tertiary level training program on vehicle electrification technology. In this training program, the target group of students to be trained and the estimated learning outcomes are taken into account before the definition of course requirements. As it was meant to serve young students, it was tailored to incorporate a variety of educational approaches and modern technologies in order for the training to be attractive, balanced between theory and practice. Therefore, a blend of theoretical lectures offered mostly online (due to COVID-19 pandemic restrictions), synchronously and asynchronously, laboratory sessions offered purely in-person, medium size projects and industrial internship is formed. The laboratory sessions assist the trainees to assimilate knowledge on most typical engineering subjects, therefore they were arranged for almost half the teaching topics. The medium size project combines the troubleshooting of a simple but typical electric powertrain with augmented reality (AR) technology [21] in order to immerse the students in engineering thinking around electric vehicles through the general principles of the project-based learning (PBL) approach [22–26]. Finally, internship in an enterprise with activities in vehicle electrification completes the overall training with a flavour of a real working environment. The curriculum is set in such a way to be feasibly adjusted according to the needs of the target group of trainees.

## TRAINING PROGRAM DEVELOPMENT

The development and piloting implementation of an attractive as well as efficient short training program on vehicle electrification requires design in a way to include modern and interesting for trainees techniques as well as a complete and adequate blend of courses. Three preliminary actions have, thus, been taken.

At first, the target group of the training and the overall framework was defined as the training material and curriculum must correspond to the knowledge background of the trainees. The training group was selected to be composed of University students. Specifically, students from the two final years of 5-year engineering University departments or from the final year of 4-year University departments of electromechanical and automotive origin were selected as the target group in an overall program that would not exceed the time limit of an academic semester. The characteristics of the selected target group are:

- knowledge of electrical and mechanical engineering fundamentals, like electric circuits, electrical machines, mechanics, machine elements etc,
- professional target in the automotive market,
- ability to fully devote themselves to the training program during its overall time period.

In the second step, the learning outcomes and the topics of the curriculum were defined. Emphasis was given to the inclusion of enough topics in order to provide a general insight to the electric vehicle technology fundamentals and, secondarily, significant depth with references to state of the art research studies on selected topics, like the energy storage systems and electric drives. This approach aims in obtaining trainees that would feel familiar with electric vehicle technology in general and, potentially, skilled enough to enter the electric vehicle market. Therefore, the teaching topics of the curriculum were appropriately selected in order to horizontally cover as much part of the core vehicle electrification technology area as possible. It focuses on applied engineering concepts and provides industry insights in order to immerse the students into the electric vehicle technology, functionality and sustainability.

The final curriculum, presented in Figure 1, was composed of twenty topics grouped into the four wider knowledge areas, namely core electric vehicle technologies from the electrical and mechanical point of view, business administration topics as well as other significant EV related topics like autonomous vehicles, life cycle analysis, smart gridding etc.

The selection of the core technological topics of Figure 1 is based on traditional EV topics, like those fully covering the electric powertrain and control, and general automotive topics of mechanical nature, necessary for the description of a vehicle's construction and movement. Additionally, the background of the students was taken into consideration for the development of the teaching material as it would be very difficult, if not impossible, for them to cope with too advanced theories. The curriculum was complemented with modern topics of the automotive industry whereas a multidisciplinary direction was also given by means of legislation, production management and marketing topics. The twenty topics curriculum was concluded with two additional educational activities, a medium sized project, split into two parts, and industrial internship. The purpose of the former was to implement project based learning approach [24, 25] by integrating the AR technology with the curriculum and providing a research insight to the students. It was characterized by large experiments that would lead to the development of a scaled automotive control system based on appropriate software and AR technology. At the same time, it would enforce the students to practice their gained knowledge. The technological outcomes of the project were presented by the students in scientific papers. Focusing on the educational approaches per topic, the students

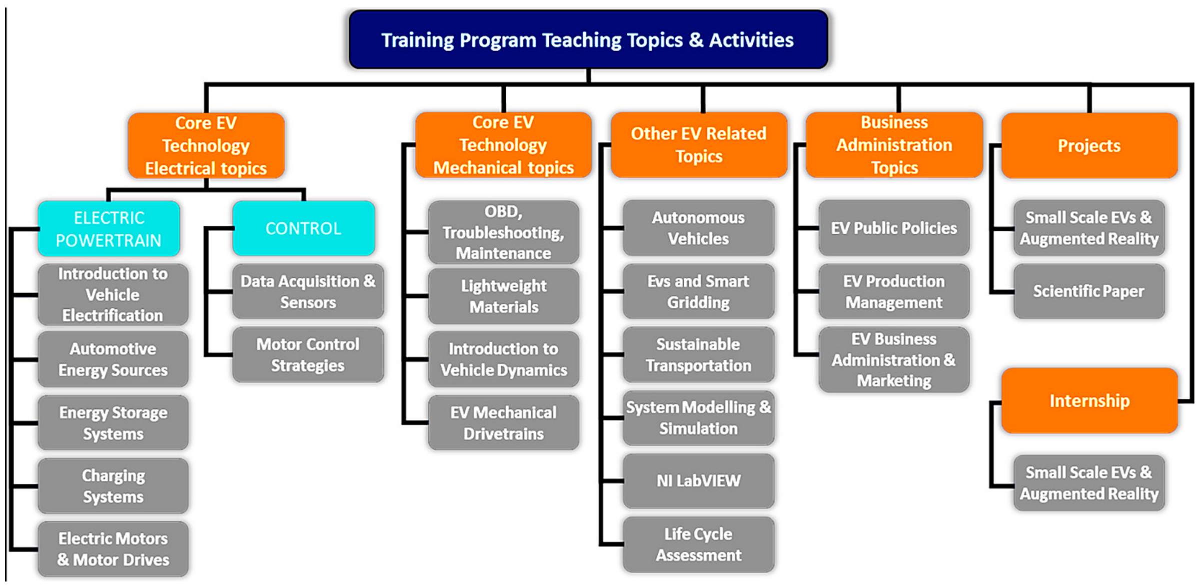


**Figure 1.** Teaching topics and activities of the proposed training program

would have to elaborate homework, personally or in groups, as well as lab reports. Table 1 presents in detail student obligations per topic. The learning outcomes of the curriculum defined the extend at which each topic would have been taught [27, 28]. Balance was maintained for all the topics. As such the learning outcomes generalized are presented below. The students should be able to:
- understand and describe the core elements of an electric powertrain as well as the fundamentals of all topics,
- perform calculations and simulations (where possible) with core elements of an electric powertrain as well as the fundamentals of all topics,
- install and setup a measurement system on an electric powertrain,
- implement Augmented Reality technology to describe and present an electrical powertrain,
- present a short project in the form of a paper.

Finally, the detailed requirements per topic and the obligations of the students in the implementation phase of the curriculum were defined. It was selected as a blend of traditional and innovative teaching methodologies involving in-class (if possible) and web based courses, traditional experimental laboratories with the ability to be implemented remotely in an effort to overcome practical problems in attendance, like the one caused by COVID-19 pandemic crisis. Simulation tools have been also a very important factor of the teaching methodology introducing the attendant students (and possibly graduates or professionals) to modern technological advances and approaches. The medium sized, project based course has brought the attendants closer to the real world of electric vehicle technology combined with simple internet of things and augmented reality applications. Finally, the overall curriculum has been complemented by two weeks of industrial practice in selected companies.

Overall, the training activities of the proposed EV training program were:
- 144 hours of theoretical lectures divided into two time periods,
- 75 hours of laboratory experiments taking place after the end of each the two periods of theoretical lectures,
- a medium sized project to be elaborated by the students in groups, that would eventually lead to a scientific type paper prepared per group.

14 days of practical training in selected enterprises taking place after the end of the previous activities.

**Table 1.** Training program student obligations per topic

| Topic title | Theoretical lectures hours / Homework | Laboratory hours / Reports |
|---|---|---|
| Introduction to vehicle electrification | 3 | |
| NI LabVIEW® training | 6/YES | 16/YES |
| Automotive energy sources | 12/YES | 4/YES |
| Lightweight materials | 6/YES | 4/YES |
| Introduction to vehicle dynamics | 6 | |
| Data acquisition and EV sensors | 6/YES | 4/YES |
| EV production management | 9 | |
| Electric motors & Motor drives for EVs | 12 | 4/YES |
| Autonomous vehicles | 9/YES | 4/YES |
| EV business administration & Automotive marketing | 15 | |
| EV system modelling and simulation | 6 | 9/YES |
| EV energy storage systems | 6/YES | 6/YES |
| EV charging systems | 12/YES | 6/YES |
| Mechanical drivetrains for EVs | 6/YES | 6/YES |
| Control system development | 9 | 4/YES |
| EV public policies | 6 | |
| EVs and smart gridding | 6 | |
| EV OBD, troubleshooting & Maintenance | 3 | 6/YES |
| Life cycle assessment of EVs | 3 | 2 |
| Sustainable transportation | 3 | |

## PILOTING IMPLEMENTATION OF THE TRAINING SCHEME

The training curriculum described in the previous section was implemented on a piloting phase. The initial design was kept intact but it was proved that many arrangements and practicalities needed to be taken into account. It must be mentioned that the program was about to be implemented during the winter semester of 2021–2022. However, due to the COVID-19 pandemic restrictions not only was it postponed by one semester (spring 2022) but special care needed to be taken and modifications to be made to the initial design.

To begin with, initially, teaching was foreseen to take place in classroom. Due to COVID-19 pandemic restrictions and protective measures, the educational scheme had to be rearranged in order to include online lectures which they became mandatory. Thus, topics without lab requirements, entailing purely theoretical content, like Business Ad-ministration, Production Management or even Sustainable Transportation and EV Public Policies, could be feasibly taught online in a traditional manner since they weren't expected to be degraded. The word "traditional" is used excessively in order to denote the typical, online teaching methodology that has prevailed over the past few years. Of course, useful tools, like special software, pen tablets etc. were exploited for more efficient online education.

In the more technical subjects like Automotive Energy Sources, Electric Motors and Motor Drives etc., the greatest part had to be taught online. The few, remaining lecturing hours together with laboratory experimental sessions were offered to the students in person. The students were divided into groups and worked for almost a month, in total, on appropriately developed experiments on selected topics, like Automotive Energy Sources, Lightweight Materials, Autonomous Vehicles etc. (Table 1). This group formation was kept intact during all activities in the effort to enforce the bonding of the group members. The same scheme was implemented for the final student projects, to be further described below. It must be mentioned that the experiments were fully supported by the experienced personnel of three Universities involved in the piloting program, as well as by rich educational material, including guidelines for the experiments, videos, software, codes etc. Lab reports were required for almost all experiments in which the results should be presented and commented on.

The most challenging part of the educational program was the medium size project, based on the principles of PBL approach that had to be worked through in two parts. During these, the students would have to familiarize themselves with Augmented Reality technology by working with a freeware software and appropriately selected or developed 3-D models of equipment and electric powertrain parts. Specifically, in the first part, the students, after been introduced to the project idea, had to attend a short, 6 – hour tutorial on AR technology and the use of the corresponding freeware software OpenSpace3D [29]. Afterwards, they had to become familiar with a small-scale electric vehicle, draw the wiring diagram of its powertrain and gather as much information as possible about its parts, like battery, motor drive, sensors etc., from the manufacturers and the internet. Also, by programming an appropriate data acquisition platform, they had to acquire data from various on-board sensors. Finally, they had to design an AR recognition coding system and develop an AR application for mobile phones and tablets in which they would integrate description files, images, 2D and 3D models as well as live sensor data acquired. The same procedure should have been repeated without the AR software but by means of appropriate diagnostic tools for a commercial vehicle as well. The projects (2nd part) were completed with the preparation of a scientific type paper that was presented in a specifically organized session of an international workshop.

The next step of the procedure included the industrial placement of the students. Its meaning is apparent, to provide the students a short but significant insight to the real world of vehicle electrification. The students were arranged into four companies and in-stitutions, all active on electric vehicle technology from various points of view. Although short in duration, the internship was balanced compared with the rest of the activities.

The course duration was four (5) months, including the 14-day industrial internship, after the end of the teaching period. The course took place mainly online except two time periods of 14 days each during which the students have participated in the large-scale laboratory sessions including the obligations for the medium sized project.

Digging further into the educational procedure, it is worth going through the path of the student groups from their initial formation to the delivery of the final paper. In the following subsections, brief descriptions of the theoretical lectures, the laboratory sections as well as of the medium size projects are given.

## Laboratory experiments

Among the twenty (20) topics, laboratory experiments were included for more than half of them, i.e. twelve (12), according to Table 1. The experiments took place in the middle and at the end of the teaching period allowing for the students to fully attend the theoretical lectures on the corresponding topics before using any experimental equipment. The experiments were of low and medium level of difficulty, aiming mostly at providing the students with insight to basic measurement procedures and parameters.

Specifically, in the middle of the teaching period, the experiments in the frame of "Automotive Energy Sources", "EV Motors and Motor Drives", "Lightweight Materials", "NI LabVIEW Training", "Data Acquisition and EV Sensors" as well as "Autonomous Vehicles" topics took place. Each laboratory session lasted for about 4 hours during which the students were introduced to the experiment by appropriate tutors, executing it and recorded the results. At the very end, a discussion between the group and the tutor was necessary in order to clarify the purpose of the experiment and its conclusion for the students to be able to work on and deliver a short report presenting and commenting on their results. Similarly, at the end of the teaching period, the experimental topics implemented were the "EV System Modelling and Simulation", "On Board Diagnostics, Troubleshooting and Maintenance", "EV Charging Systems", "Energy Storage Systems", "Control System Development" and "Mechanical Drivetrains for EVs" ones.

In the following subsection, the experimental procedures for the topic of "Automotive Energy Sources" are briefly presented. Similar experiments have been set up for the other topics too, having low to medium difficulty but aiming at delving the students into basic elements of the topic.

### *Automotive energy sources*

The main purpose of the experiments is to familiarize the students with the concepts and techniques of discharging battery types, which are used in automotive energy systems as well as with supercapacitor charging and discharging. The first part of the exercise refers to the discharge of batteries and the second part refers to charging and discharging procedures of supercapacitors. During the experiments four types of energy sources were utilized:

- Lithium-Ion batteries,
- Lithium Polymer batteries,
- $LiFePO_4$ (LFP) batteries,
- Supercapacitors.

For the discharge procedure a set of proper resistive loads was set up, consisting of a variable resistor and a set of automotive lamps. The experiment started with the batteries fully charged. Voltage and current were monitored and recorded at predefined time in-tervals as the batteries discharge. A graphical plot of voltage versus battery's depth of discharge (DOD) had to be produced by the students. Similarly, in the case of supercapacitors a dedicated charging and discharging circuit was set up by the students. Voltage and current were monitored and recorded at prede-fined time intervals as the supercapacitor charged or discharged. Two graphical plots, battery voltage versus time and current versus time had to be produced by the students, both for charging and discharging. The experiments aimed mostly at providing an insight to the relationship between voltage and DOD of the batteries, while simultaneously giving a hands-on experience of various energy sources to the students. In the case of supercapacitors the relationship between voltage, current and time were emphasized. The materials and equipment used for the exercise were:

- lithium-ion battery consisting of ten 3.6 V modules connected in series. each module consisted of 5 cells in parallel. the nominal voltage of the battery was 36 V and the capacity was 14.5 Ah,
- lithium-polymer battery composed of five 3.7 V cells in series. it had a nominal voltage of 18.5 V and a capacity of 5 Ah,
- LFP battery composed of four (4) cells connected in series. the capacity of the battery was 8 Ah,
- two automotive headlight lamps and two automotive rear signalling lamps at 12 V nominal voltages used as loads in various combinations,
- a variable power resistor of 5 Ω and 16 A used as a ballast only in the case of the 36 V lithium ion battery, due to its voltage being much higher than 12 V.
- handheld millimetres used as DC voltmeter and DC ammeter or DC current clamp used to monitor electrical parameters,
- timer required for measuring time intervals.

The circuit configuration used in the case of the lithium-ion battery is indicatively shown in Figure 2.

### *Student transitional project*

Student transitional project was part of the training that brought students closer to the engineering thinking. The purpose of the project was to force the students to work together on a small scale electric vehicle as well as on an actual commercial electric vehicle. In the first one, the students would be able to work with a relative freedom as the vehicles were custom made for laboratory purposes but incorporated a scale down in size and power of a powertrain. The second one would provide the students the feel of the real world and the opportunity to perform powertrain measurements on a commercial electric vehicle.

The idea lying behind the medium size project was to make the students learn the basics of the powertrain of an electric vehicle. For this reason, the Augmented Reality technology was used that would make the overall project more attractive to the students. The procedure can be described in two phases.

In the first phase, the students worked on an existing small scale EV using all the appropriate components. They had to re-assemble its powertrain, perform troubleshooting and overcome deliberately created faults on the vehicle. Then, during vehicle operation, current, voltage, speed and temperature values, depending on the case, were acquired by available data acquisition systems and LabVIEW® software in order to produce a scaled automotive control system.

In the second phase, AR technology should be exploited by the students in order to produce an Android application, appropriate for computer, tablet or mobile phone, that would provide useful information about the vehicle to anyone who would use it, based on QR tags. Specifically, they had to gather information about vehicle's powertrain from various available sources, like the manufacturer of a part, the internet etc. Specifications, 3D solid models, images or operational data were mostly included in the gathered material. Then, a QR code system should be developed in order to allow any Android device to recognize the vehicle and all its powertrain's parts. Through this system the user of the Android device would have access to the available information about the vehicle and its powertrain. The ultimate challenge for the students would be to connect the AR code with one of the sensors and download data to the Android device. It must be mentioned that all students had to attend a short course on AR and they were systematically tutored by experienced on AR personnel.

The purpose of the tasks in the medium size projects was to familiarize the students with the

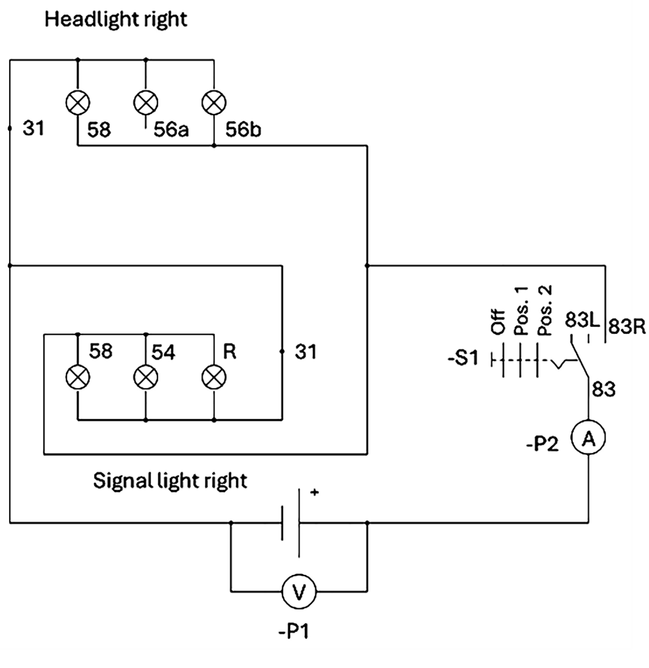


**Figure 2.** Electric diagram of the measurement circuit used in the frame of the "Automotive Energy Sources" laboratory experiments

idea of the electric powertrain and to enforce their electric vehicle hands-on experience in a safe, for them and the vehicles, environment, thus bringing into action knowledge acquired via all preceding laboratory sessions. AR technology provided a modern and attractive means to help them further delve into the world of vehicle electrification in a very creative manner developing IT skills also.

The following small scale vehicles, depicted also in Figures 3 were utilized in the first part of the project, one per student group:

- e-bike,
- delta type e-trike,
- tad-pole type e-trike,
- electric kart,
- small scale electric utility vehicle with the ability to perform semi-autonomous movement.

A typical case of the medium size projects involved the custom made electric delta type tricycle of Figure 3b as the core element. Initially, the trike was checked for any possible electrical or mechanical malfunctions. The students performed maintenance on the mechanical parts of the vehicle. Regarding the electrical components of the vehicle, the motor's operation was checked by means of appropriate software. Battery was also inspected and measured. The other small scale EVs used by other groups were all characterized by simple powertrain but ideal for introducing students to the world of vehicle electrification.

In order to make the introduction to the AR technology easier, the freeware version of the Autodesk® Tinkercad software [30] was chosen as the appropriate computer aided design environment for the 3D modelling of the delta trike. The specific software was selected since an STL type file, essential for the development of an AR application, could be exported from it. Figures 4 depicts the trike 3D model as developed in Autodesk Tinkercad software.

Following, the 3D model together with other descriptive files and 2D images were used in conjunction with the OpenSpace3D software in order to


**Figure 3.** Small scale vehicles of the Laboratory of Energy Systems of the International Hellenic University used for the Student Transitional project: a) electric bicycle, b) delta type electric tricycle, c)tad-pole type electric tricycle, d) electric go-kart, e) small scale electric utility vehiclewith the ability to perform semi-autonomous movement

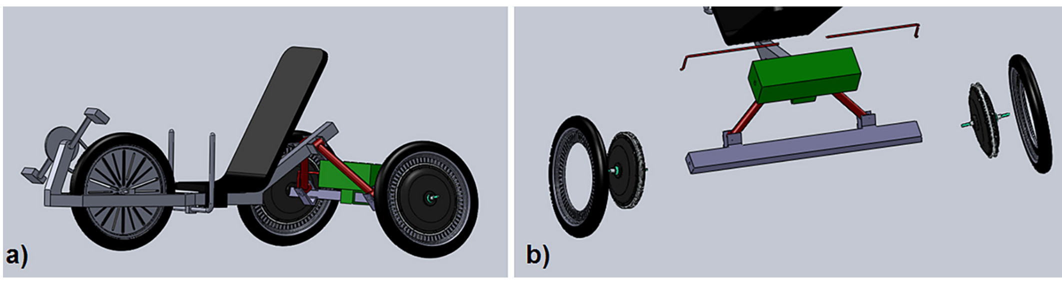


**Figure 4.** Delta type electric trike 3D models: a) complete vehicle, b) rear wheels and axis

develop the final AR application for displaying the designed model alongside all the technical data and specifications of the vehicle's parts (Figure 5a). After the initial version of the model, extra capabilities were added to the AR application, such as measurements from the throttle circuit of the vehicle using an Arduino Uno microcontroller and a potentiometer that provided the throttle output. The values were displayed in the AR application interface.

As an example, Figure 5b depicts part of the AR code implemented. The equipment used in the case of an electric bicycle as the subject of the project was:
- delta tricycle chassis,
- battery pack for e-bikes,
- electric motor (in-wheel) for e-bikes,
- current transducer AT 50 B5 LEM,
- voltage transducer DVL 50-UI LEM,
- speed sensor, inductive type,
- battery temperature sensor, thermocouple,
- arduino uno and accessories,
- personal computer with LabVIEW installed,
- cables, connectors and fuses.

Similarly, the equipment used in the case of an electric go-kart as the subject of the project was:
- electric kart chassis,
- battery pack for electric kart,
- electric motor (PMSM type),
- current transducer at AT 50 B10 LEM,
- voltage transducer DVL 50 LEM,
- speed sensor, resolver type,
- throttle pedal sensor, potentiometer,
- battery temperature sensors, thermocouples,
- NI cDAQ 9164 and accessories,
- personal computer with LabVIEW installed,
- cables, connectors and fuses.

The students were assessed according to the deliverables of their project which for phase one were:
- fully operational electric vehicle,
- operational sensor kit,
- brief report of the e-trike and sensor kit operation,
- 7 minutes presentation of the e-trike and sensor kit operation,

and for phase two:
- fully operational AR code,
- fully operational data acquisition system,
- brief report of AR code and data acquisition system,
- 10 minutes presentation of the overall project.

In the second part of the project, the student group had to troubleshoot the Toyota Yaris Hybrid 1.5 HSD, P13, VNK, 55 kW model line of 2014–2020 (Figure 6). Under constant supervision, the typical On Board Diagnostics (OBD) codes were used in order to troubleshoot the given vehicle. Real time driving conditions were simulated by means of a chassis dynamometer and all graphs depicting the state of charge of the battery and the rotational speed of the electric motor were recorded through the Bosch ESItronic 2.0 software and the Bosch KTS 570 diagnostic tool.

### *Practical training and industrial involvement*

The last training activity, taken place after the end of the teaching period, was the industrial internship. Students that had actively participated in the theoretical lectures and laboratory courses and submitted the deliverables of the medium size project, were spread as interns into four (4) enterprises active on electric vehicle technology. The activities of each group are briefly described below.
- The first company had an expertise in the retrofit of solar panels into a hybrid electric vehicle for the charging of high voltage batteries and the development of real-time solution for the optimized reduction of energy consumption, continuously adaptable to any variation of route, traffic and payload (load).

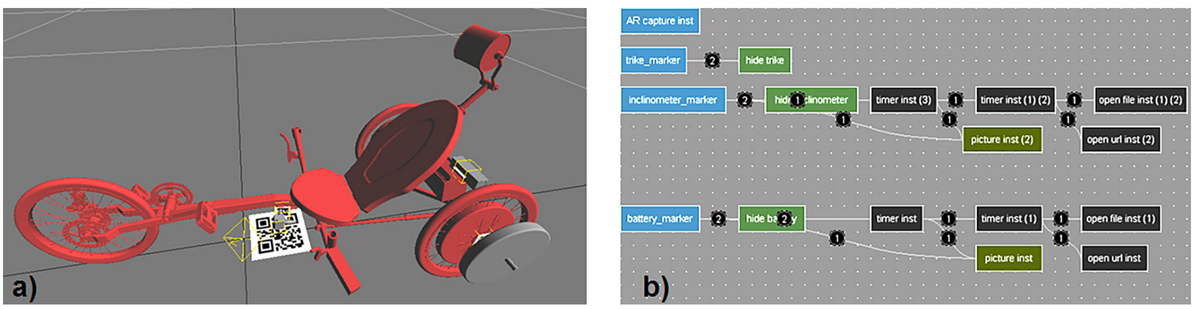


**Figure 5.** A view of: a) snapshot from the screen of a mobile phone with the AR application, b) part of the AR code implemented

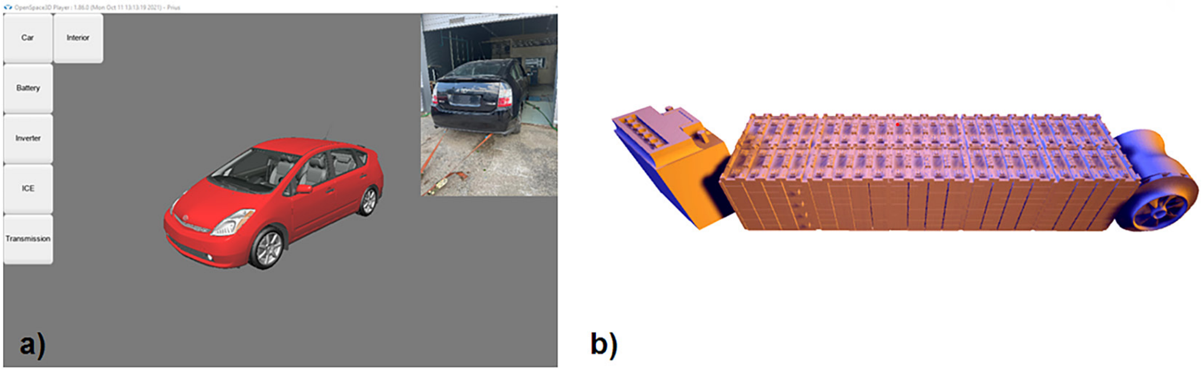


**Figure 6.** A view of: a) Snapshot of the AR application developed for the Toyota Yaris Hybrid vehicle of the Casimir Pulaski Radom University; b) 3D model (left to right) of the backup lead-acid 12 V battery and the lithium-ion battery consisting of 48 cells reaching the nominal voltage of 177.6 V and capacity of 4.3 Ah

Additionally, a visit to the premises of STMicroelectronics Inc. for demonstration of a system for the electronic management of electric motors was arranged.

- In the second enterprise, the expertise of which was the development and production of a utility, light electric vehicle, the students were further divided into groups and worked on a computational fluid dynamics software to estimate the aerodynamic coefficient of the vehicle, on the development of the battery charger, on the training of the company's artificial intelligence software for the recognition of objects during autonomous parking and on the assembly line of the ventilation system.
- The third group of students has worked on the OBD system and data acquisition from a BMW i3 electric vehicle together with battery pack development techniques and 3D design of a battery pack from a semi-complete model.
- The fourth group was trained on the techniques for the development of e-bike bat-teries whereas at the same time attending seminars for Level 1 and Level 2 high voltage technicians with a focus on diagnostic skills

## TRAINING PROGRAM STATISTIC

The training program, as presented in the previous sections, was deployed from February 2022 to June 2022. The first teaching period of online theoretical lectures was concluded with two weeks of in person laboratory courses at the end of March 2022. Similarly, the second teaching period was concluded with laboratory courses at the end of May 2022 whereas the last month was totally devoted to the medium size projects and the practical training.

Students coming from three Universities have participated. Among the 36 of them that were initially enrolled and completed the first teaching period, 35 have continued and successfully completed the first laboratory period, due to the pandemic. This number did not change until the end of the second teaching period, online and in-person. However, only 29 students participated in and completed the internship, due to the obligation to travel abroad. Coming to the trainers, 18 persons have participated in the online lectures and additionally 6 technicians have tutored the students during the laboratory courses. In total, taking into account that the overall teaching hours were 144 for lectures and 75 for laboratories, 8 lecturing hours corresponded per trainer and about 12.5 hours per technician. However, it must be mentioned that during the laboratory training, all trainers were actively working with the students in order to assist them to successfully complete all the experiments.

Regarding the enterprises involved in the overall procedure, four small and medium enterprises as well as a research institute have accepted students for internship. All of them have actively participated in the teaching procedure also either with specialized lectures about their activities and products or through equipment lent and demonstrations during the laboratory courses.

Finally, after the end of the teaching period, including the internship, the students were given the opportunity to receive a skill certification by taking exams related to the course. The skills were totally connected to the estimated learning outcomes of all teaching topics as they were initially defined before the deployment of the piloting course. A specialized, automotive skill certifier [14], has assisting towards the definition of the skills with regard to the learning outcomes and the general needs of the industry. Eventually, among the 29 students having successfully completed the training, 24 took the exams and only 16 have finally achieved the skill certification reward.

## DISCUSSION AND CONCLUSIONS

The educational program presented in this paper is a blend of diverse learning approaches, from synchronous and asynchronous online teaching to project based teaching, implemented in order to train students on vehicle electrification technologies. This blended training form, but mainly the strong laboratorial and project based one increased the interest and active participation of the students throughout the overall training period. Although a balance between all the teaching approaches was kept, it is believed that more experimental sessions would be more beneficial. Laboratory experiments are always very educational and increase understanding. Towards the same direction, the AR inclusion in the final project gave an additional motivation. It provided a better insight to vehicle electrification technology as it forced the students to work with the simplified but realistic powertrains and powertrain parts' datasheets.

The overall training approach could be considered as one among various targeting students to be educated on vehicle electrification. However, the critical part strongly connected to the sustainability of the program is the final skill certification of the students. This program was built to provide horizontal training to the students. Similarly, another training course on vehicle electrification could be developed based on the same principles as the one presented in order to cover the needs of other target groups, from more advanced, e.g. in a postgraduate University level to purely professional aiming at people already employed in the automotive sector.

Starting from the three axes presented in section two, i.e. the target group, the learning outcomes and the course requirements, with the connection to professional skills dictated by the industry, a similar blended learning approach tailored for any particular case can be feasibly developed and deployed. Since the wheel must not be reinvented, continuous observation and recording of problems arise as well as good practices is of significant importance for the sustainability and future versions of the educational program. Improvements that can be made include:

- the constant need and support of the overall procedure by an efficient e-Learning platform;
- the use of focused lecture notes and tutorials;
- well designed laboratory sessions with updated experiments;
- more interactive real experiments or even design of additional remote experiments;
- participation of more teachers in the training activities, especially representatives of the industrial world;
- in-situ visits to industries and enterprises with significant vehicle electrification activities and products.

In total, it seems that the blended learning approach and the exploitation of modern technology increase the interest of students, their commitment and knowledge assimilation at the cost of greater efforts required by the trainers and from the students themselves. It will be a real challenge to develop a series of training courses, thus extending the target group from the tertiary education student level that was presented to vocational level.

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