# An adaptive e-learning platform for the qualification for working on electric vehicles


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***Abstract*—The popularity and the sales volume of electric vehicles increased in the last years. This change in the automotive industry leads to new challenges for the training sector. Therefore, the education programs for employees in the area of motor vehicle service, rescue teams, and other relevant occupational groups need a modification for the topic e-mobility. The paper presents a prototype of an adaptive e-learning platform for the qualification of working on electric vehicles that is developed within the project EmoTal, which is funded by the German Federal Ministry for Education and Research. The target groups of the training program are professionals (e.g. motor mechanics, first responders, fire fighters). The developed blended learning concept includes beside the adaptive e-learning platform some face-to-face instructions, practical training, m-learning, different kinds of tests (e.g. entrance test, final examination) etc. Furthermore, the e-learning platform provides the opportunity of the implementation of simulations, like interactive measurements at an electric vehicle. This is very important in relation to the potential health risk by working on an electric vehicle's high-voltage system.**



***Keywords—electric vehicle; adaptive; e-learning; lifelong learning, blended learning***


## I. Introduction

On January 1, 2015, 1.3 million electric vehicles (EVs) were on the worldwide streets [1]. In comparison to this, the total number of worldwide passenger cars in 2014 was approximately 0.9 billion [2]. Therefore, EVs have only a very small share of all vehicles worldwide. Nevertheless, the sales volume of EVs will increase in the future. For example, the European Union aims to achieve 8-9 million [3], the USA 3 million, and China 11.9 million EVs on the streets by 2020 [4]. Reasons for buying an EV are for example the rising environmental awareness of potential buyers or the potential of lower operating costs of EVs.

Based on this development, the qualification for working on EVs becomes more and more important. Especially the service sector is a very important part to increase the customer satisfaction. Hence, the motor vehicle service area needs highly qualified employees for working on EVs. For the clarification of the necessity of a training program for working on EVs some facts about the number of motor mechanics in Germany and the USA are listed below: In 2014, 739,900 automobile technicians and mechanics are employed in the USA [5]. In comparison to the USA, 462,000 people are employed in the vehicle service area in Germany in 2014. Approximately 62,500 of them are employed as motor mechanics and 79,000 as automobile technician [6].

However, the potential occupational groups which have contact to EVs in their everyday working life are not only employees in the area of repair services. For example, firefighters, police officers, employees of towing and breakdown services or rescue teams need a good qualification for the topic e-mobility as well.

## II. Related Work

### A. Education for Working on Electric Vehicles

As already stated, the sales volume of EVs will increase more and more in the future. Therefore, a lot of training programs for the qualification for working on EVs were presented in the past. The majority of this programs is located in the area of academic education (e.g. [7], [8], [9]). A detailed overview of activities of German universities as well as training organizations are presented in [10] and [11]. Based on this, there is an urgent backlog of training programs for professionals.

In context of the project goal, development of a training program for professionals, it is indispensable to analyze current further education concepts for professionals. Currently, the National Alternative Fuels Training Consortium (NAFTC) offers an education program for different occupational groups like automotive technicians, charging infrastructure engineers or first responder [12], [13].

Another relevant training program is the "Hybrid and Electric Vehicle Engineering Academy" of the Society of Automotive Engineers (SAE) [14]. With this program the SAE offers an opportunity for mechanical and electrical applications engineers, design engineers, and some further occupational groups to qualify themselves for working on EVs.

In comparison to the programs of the NAFTC and the SAE the aim of the training program presented in this paper is to develop an adaptive and personalized training program, which considers the different learning styles, prior knowledge, and individual learning objectives based on the occupation of the participants. With this adaptive approach the project team improves the quality and the efficiency of a training program for working on EVs in the area of non-academic education.

## B. Adaptive Training Programs

Adaptive e-learning is not a new learning style. There are a lot of papers which were published in the past. In 2005, the authors of [15] already clarify the disadvantages of conventional e-learning platforms and the advantages of an adaptive approach. From the authors point of view an e-learning platform without an adaptive structure is like a pure information warehouse and does not take into account the individual learning style or level of knowledge. This opinion is already shared by the authors of [16] and [17].

Hence, one of the most important distinctive points of an adaptive approach in comparison to conventional web-based learning is the opportunity of an individual adjustment of the learning content based on the personal prior knowledge and the individual learning goal. The individual adjustment leads to an enhancement of the learning quality and efficiency. This advantage is also highlighted in [15], [18], [19].

One key goal of the training program should be the implementation of animations, simulations, and video material. Especially the providing of simulations (like interactive measurements at an EV) makes a practical oriented training program possible. The benefits of simulations are inter alia the cost savings for expensive equipment and this approach ensures the safety of the participants [20]. The last mentioned point is very relevant in relation to the high-voltage system of an EV and the potential health risk by working on an EV.

In summary, there are lot of training programs for the topic e-mobility. The majority of the current programs are for the academic sector. In relation to the increasing popularity of EVs the number of training programs for professionals will raise in the future. Hence, the realization of an adaptive program for the qualification for working on EVs relating to the non-academic education for professionals is a promising approach for the enhancement of the learning quality and efficiency.

# III. Description of the Project

The following sections describe the project goal and present the potential occupational groups of the training concept for the qualification for working on EVs. In comparison to prior literature as well as other projects relating to the qualification for working on EVs the project EmoTal aims to develop an adaptive training program with a very detailed modular design. The adaptability offers the possibility to train different occupational groups like car mechanics, rescue teams or employees of towing services with only one training program. This feature is very innovative in comparison to other relevant projects and very significant in relation to the diversity of the several employees, which have contact to EVs in their working life.

The adaptive e-learning platform is only one part of the total training program. Other didactic methods are mobile learning (m-learning), face-to-face instructions, practical instructions, practical training or lecture. The utilization of a blended learning concept has many advantages like promoting the self-study of the participants or the integration of practical exercises. These advantages of a blended learning concept outweigh the disadvantages of pure e-learning (e.g. reduction of the social contact) or pure face-to-face instructions (e.g. no flexibility in place and time). The flexibility of the e-learning platform in place and time is very advantageous for the selected target groups (“extra occupational education”). After a successful graduation of the training program, the participants receive a personal certificate for working on EVs. A detailed overview of the several didactic methods and features of the training program is presented in [11].

For reaching the project goal the project partners use different methods. One approach is the distribution of logbooks to drivers of EVs to identify errors in the everyday use of EVs. Other methods are surveys with several occupational groups, expert interviews, and the analysis of current literature. Based on the results, the training program is being developed by the *University of Wuppertal* in cooperation with the *German Technical Inspection Association* (*TÜV*). This cooperation between industry and science makes a practical and especially industry-oriented training program possible.

# IV. Current State Of The Project

## A. Adaptive Approach

The unique selling point in comparison to other current training programs for the topic e-mobility and thus the centerpiece of this training program is the adaptive approach. As shown by Fig. 1 the implementation of this approach allows a personalized adjustment of the learning content for different occupational groups (OG). At the beginning of the training program the participants must pass a placement test (PT) to achieve this goal. Based on the result of the PT, the several participants are assigned by a classification procedure. This step allows an individual classification in relation to the prior

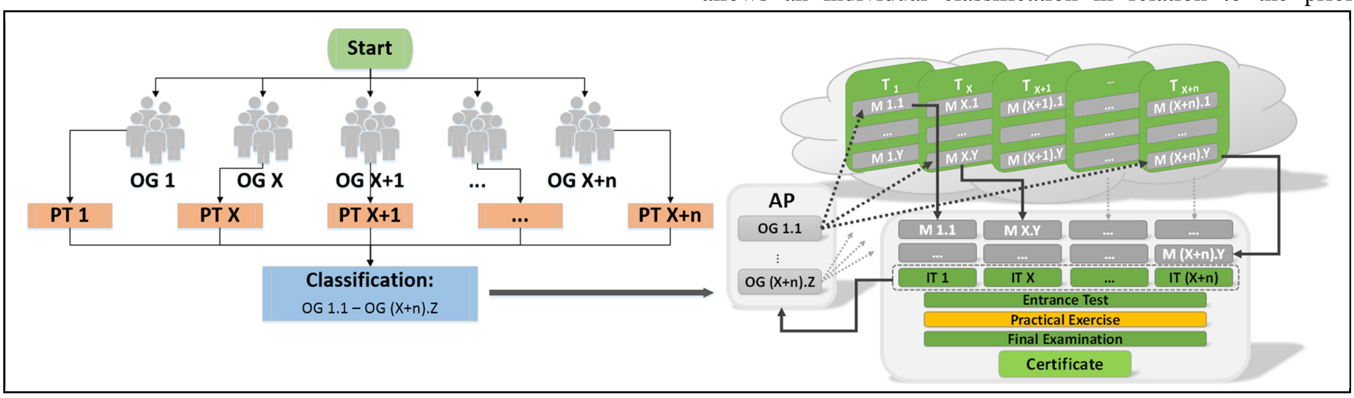


Fig. 1 Adaptive structure of the modular design.

knowledge as well as the strength and weakness of the participants. Therefore, an optimal allocation of learning content is feasible.

The participants are classified into different levels of knowledge. In order to clarify the procedure, the following example gives a good insight. One participant of OG 1, in this case a motor mechanic, would be assigned to the classification level OG 1.1 after passing PT 1. This level is for participants with a very well prior knowledge in electrical engineering. Another participant with a lower prior knowledge in electrical engineering maybe is assigned to OG 1.2 or OG 1.3. The PT is expandable for different occupations if necessary. Other conceivable classifications are a

- firefighter with a very good knowledge for working on EVs (OG 3.1),
- an employer of a towing service with poor knowledge in working on EVs (OG 4.3) or
- a paramedic with average knowledge in rescue people who are in involved in an accident with an EV (OG 5.2).

The classification process and the PT are the first steps of the adaptive approach. The next step is the assessment process (AP), see Fig. 1. The AP allows an individual allocation of the learning content based on the result of the PT and the respective occupation of the participants. To realize this approach, the project team develops a very detailed modular design. The current modular design for motor mechanics includes 17 topics ("T 4: electrical risk" etc.) and 111 modules ("M 14.1: personal protective equipment" etc.). A more detailed overview is presented in [11]. In comparison to this, the current modular design for firefighters includes 8 topics ("T4: rescue measures" etc.) and 43 modules ("M 5.1: lithium-ion battery" etc.). At this point it should be noted that the development of the modular design is an iterative process and varies during the whole duration of the project EmoTal.

Furthermore, the total number of modules are solely visible for the developer, administrator or trainer and the participants are only able to see the personalized compilation of the several modules. The high number of modules allows the utilization of only one module (e.g. "ventricular fibrillation") for several occupational groups (e.g. motor mechanics, firefighters), see Fig. 1.

## B. *Interactive Measurements*

After each topic and thereby after finishing all modules of a topic the participants must pass an intermediate test (IT), see Fig. 1. The adaptive approach provides the allocation of personalized learning content based on the results of the IT. Hence, the system detects for example the knowledge gaps of the participants and make necessary learning content available to reduce or in the best case to eliminate these gaps.

One highlight of the training program is the implementation of interactive exercises. This methodological approach leads to practically oriented exercises and a realistic representation of necessary work steps by working on EVs. For the development of these kind of exercises the project team uses the authoring software ZebraZapps [21].

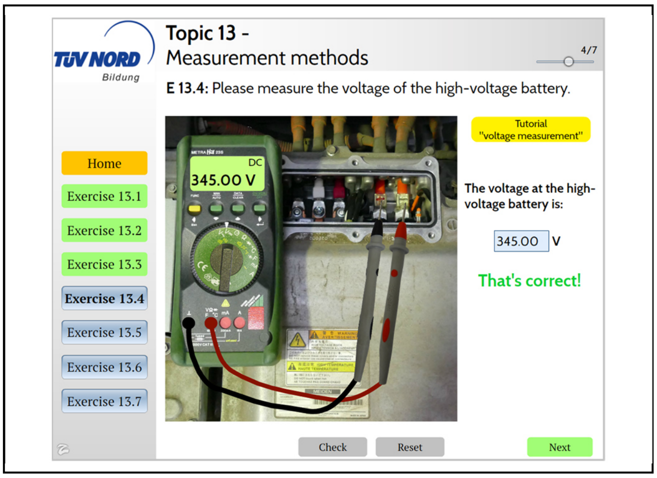


Fig. 2 Prototype of an interactive measurement of the battery voltage.

One example for an interactive exercise is presented in Fig. 2. This figure illustrates the voltage measurement of the high-voltage battery ("E 13.4"). The wires and measuring tips can be moved freely like in reality. Moreover, the participants have the possibility to turn the measuring instrument on or off (including beep) and to change the measurement range. The change of the polarity is also possible. All the mentioned features lead to a very realistic measurement. After the participants give the correct answer the button "Next" is visible, so the next exercise is accessible. Otherwise, the participants have the option to view a tutorial to learn how they can measure the voltage correctly, see Fig. 2 (yellow button).

The next exercise is the interactive measurement of the insulation resistance ($R_{In}$) of both wires of the high-voltage battery, see Fig. 3. The check of the insulation resistance is inter alia a daily task for a motor mechanic who works on EVs. After the correct measurement of the insulation resistance, the participants must give an assessment whether the insulation resistance is sufficiently high enough or too low in accordance with DIN VDE 0100-600 ($V \leq 1000\ V\ DC; R_{In} \geq 1 M\Omega$) [22].

The further exercises of this topic are for example multiple-choice questions or matching exercises (correct assignment of the five safety rules etc.).

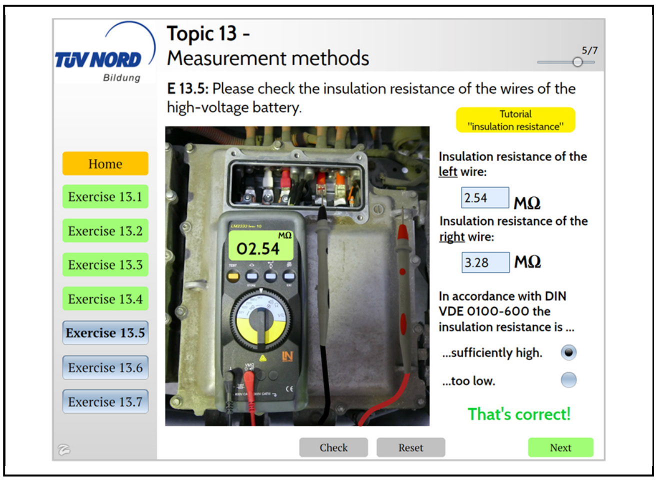


Fig. 3 Prototype of an interactive measurement of the insulation resistance.

### *C. Video Tutorials and Background Informations*

To address the different learning styles the adaptive e-learning platform provides beside the interactive exercises a lot of videos (instructions, lectures etc.). Therefore, the participants have the opportunity to watch a video tutorial about the correct handling for the measuring of the insulation resistance, as shown in Fig. 4. In this video (including sound track) the trainer shows how the participants can change the voltage range of the measurement instrument and how they can measure the insulation resistance correctly.

The provision of video tutorials is inter alia a very important point for the target group "firefighters" and "rescue teams". The implementation of a practical exercise at a damaged EV for every participants is very expensive as well as unrealizable. Hence, the videos give a good insight in the necessarily rescue measurements for working on a damaged EV respectively to rescue the people insight the EV.

For the deepening of the knowledge, the e-learning platform provides background information for every topic. Fig. 5 gives a good insight how the preparation of the background information could be visualized. This figure presents background information for topic 14 ("T 14: safety requirements 2") or more precisely for the clarification of the safety rules in relation to high-voltage systems ("I 14.4"). The target of "I 14.4" is the knowledge transfer of the five safety rules of DIN VDE 0105-100 [23]. The inherence of the five safety rules is indispensable in the context of the potential electrical hazard of the high-voltage system. A good detailed demonstration of the five safety rules for working on EVs is presented in [24], but the study of the emergency response guide of the respective EV is necessary.

In addition to the several exercises, the project team is developing some practical exercises at a demonstrator for EVs with harmless voltages (<48 V DC). The demonstrator makes a practical oriented exercise possible. For example, the participants have the opportunity to carry out the five safety rules.

The presented diversity of different exercises is completed by face-to-face instructions, practical instructions as well as m-learning. The development of an application for a mobile device offers a lot of advantages, for example the access to the learning

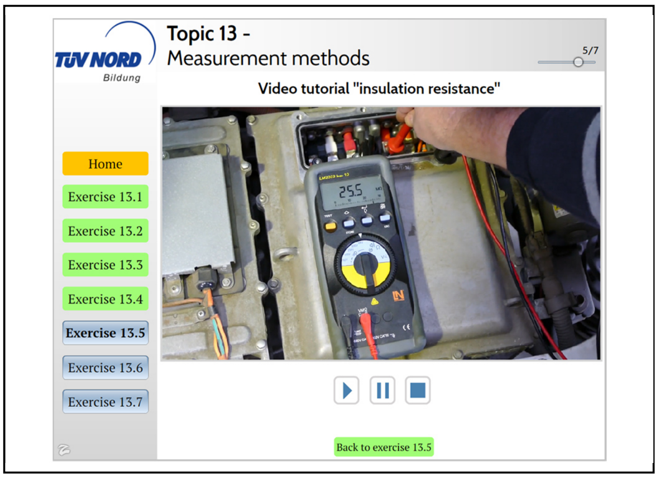


Fig. 4  Prototype of the video tutorial " insulation resistance".

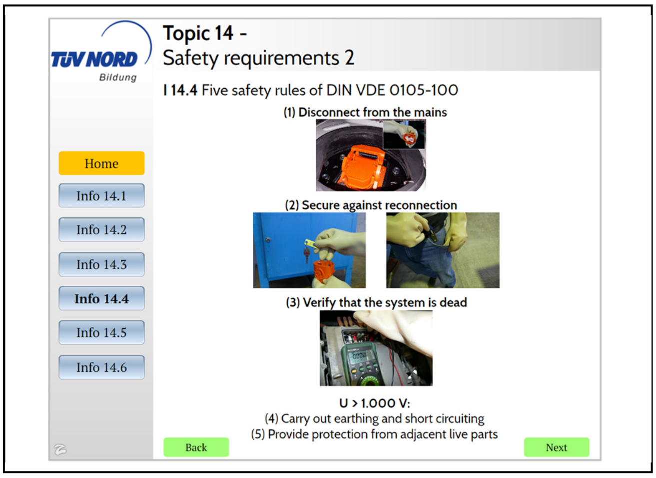


Fig. 5  Prototype of background information of topic 14

content anytime and anywhere. The presented training program uses m-learning for the exam preparation of the participants. The app mainly includes multiple-choice questions and background information like "I 14.4", see Fig. 5. The project team performed a survey with 63 future master craftsmen in the area of motor vehicle service. One result of the survey is, that 49.21% of the interviewees intend to use the app for the exam preparation. Hence, the implementation of m-learning into the blended learning concept is very important to comply the user requirements. More results of the survey are published in [11].

## V. Conclusion And Future Work

The paper presents a novel approach for an adaptive training program for the qualification for working on EVs. The research results show that there are already a lot of training programs. However, the majority of the existing training programs is for the academic sector. Hence, the potential target groups of the presented training program are employees with professional experience (keyword: lifelong learning), like firefighters, motor mechanics or staff of towing and breakdown services.

The advantage and therefore the distinctive point in comparison to the existing programs is the adaptive approach and a very detailed modular design. Based on this promising approach, the consideration of the individual prior knowledge, different preferred learning styles, and targeted learning objectives, depending on the respective professional skills, are feasible. Especially the implementation of interactive measurements is very important in relation to the potential health risk of the high-voltage system and to make a practical oriented exercise possible.

The next steps of the project are the finalization of the clarification and assessment process, the completion of the several exercises and background information, and the implementation of a field test (evaluation etc.) at one training center of the TÜV NORD Bildung GmbH & Co. KG to identify the needs of optimization. This methodical approach enables the enhancement of the learning process for the qualification for working on EVs.

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