Evaluation and assessment of a novel training program for working on electric vehicles

Heiko Fechtner, Murat Ismail, Benedikt Schmuelling
E-Mobility Research Group
University of Wuppertal
Wuppertal, Germany
fechtner@uni-wuppertal.de

Karl-Heinz Saes
Training Center Kamp-Lintfort
TÜV NORD Bildung GmbH & Co. KG
Essen, Germany
ksaes@tuev-nord.de

***Abstract*—On the one hand the growing spread of electric vehicles and hybrid electric vehicles is a positive signal with regard to the achievement of international climate protection targets. On the other hand the increasing number of electric vehicles leads to a necessary adjustment of several production processes in the automotive sector. In addition to that, the companies of the service sector need to adjust their service offers as well. Hence, there are a many employees, who now possibly get in contact with electric vehicles in their everyday working life. In other words, the qualification of the employees for working on electric vehicles is an important topic for the education sector. Therefore, this paper presents the evaluation results of 120 participants (firefighters and students) of a new e-learning platform for the qualification for working on electric vehicles in Germany.**

Keywords—e-learning; blended learning; electric vehicle; evaluation; further education

I. Introduction

The growing spread of electric vehicles (EVs) leads to new challenges for the education sector. Approximately 1.26 million EVs have been sold until the end of 2015 [1]. Hence, apart from training programs for apprentices, the development of special training programs for the area of further education is a key factor for the realization of a sustainable mobility. Electric mobility (E-Mobility) is part of the training program of motor mechanics in Germany since August 2013 [2]. Therefore, trainees, who began their education before August 2013, and professionals, who successfully finished their training before August 2013, need an additional training for working on EVs. The project "EmoTal – User Centered Electric Mobility Wuppertal" [3], which is funded by the German Federal Ministry for Education and Research since 2014, has, among others, the goal to develop novel didactic concepts and training programs to meet those challenges. The German Association for Technical Inspection ("TÜV NORD Bildung GmbH & Co. KG") and the E-Mobility Research Group of the University of Wuppertal (Germany) are responsible for reaching this goal. The centerpiece of the newly developed blended learning concept is an e-learning platform. This platform contains animations, video tutorials, interactive exercises with a practical orientation etc. The target groups of this training concept are primarily firefighters, paramedics, employees of breakdown and towing services, and motor mechanics. One further goal of this project is the development of an adaptive e-learning platform [4].

Recently a few science publications have been published, which deal with the training needs with regard to the growing spread of EVs. The authors of [5], [6], and [7] highlight e.g. the training needs for different occupational groups. One finding of [6] and [7] is the fact that the academic sector already offers a high number of programs for the qualification for working on EVs (e.g. [8], [9]). Compared to the academic sector, the number of programs for apprentices and especially for professionals with work experience (e.g. [10], [11]) is considerably smaller [6], [7]. In [5], the authors present the results of the analyses of the training needs for fire departments and fleet managers. They highlight the great optimization potential for existing training programs. In addition, the authors of [12] illustrate the challenges for the Slovak education sector depending on the increasing sales number of EVs. They emphasize the high investment requirements for the development of a specialized training program for the topic E-Mobility. Thus, they propose a cooperation between an academic partner and an industrial partner, like the cooperation shown in this paper, as well as the establishment of university networks.

II. Presentation of the Training Program

Already published papers illustrate different definitions of blended learning (e.g. [13] and [14]) and the authors of [15] underline that there is no uniform definition for blended learning. However, this developed e-learning platform is part of a blended learning concept that contains, among others, m-learning, practical training, and face-to-face instructions (see Fig. 1). The goal of the application of the several didactic methods is to combine the strength of the different methods and

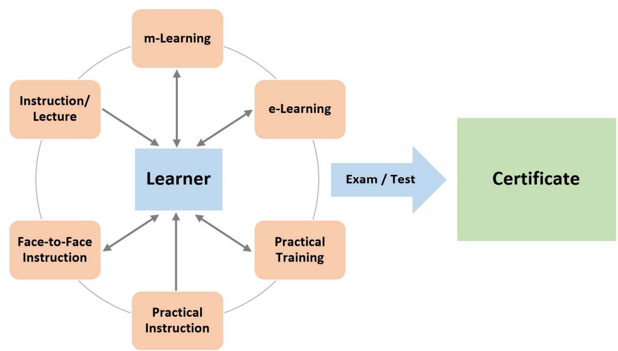

Fig.1. Didactic concept of the training program [7]

to reduce their weaknesses. On the one hand, a pure e-learning program has the disadvantages that the social contact between the participants is lower in comparison to a face-to-face program [16], [17]. On the other hand, an e-learning program has the advantage of accessing the learning content anytime and anywhere ("24/7") [18]. Another reason for the use of blended learning methods is their potential to improve the motivation and satisfaction of the participants, which is for example shown in [19] and [20].

Working on EVs possesses another type of occupational risk compared to common work steps at a conventional vehicle (e.g. with an internal combustion engine). For example, the disregard of the five safety rules (switch-off, safeguard against reconnection etc.) can cause a ventricular fibrillation or any other health risks like burns [21]. Hence, the requirements for the everyday work routines of different occupational groups (firefighters, motor mechanics etc.) have been changed. For the reduction of the occupational risk, the presented e-learning platform includes e.g. interactive measurements at several components of an EV (e.g. measurement of the insulation resistant at the wires of an inverter). This approach makes a practical oriented preparation of the participants possible. Therefore, the participants are well equipped for the practical exercises and thus, the occupational risk can be minimized.

The training program consists eight topics (T), like "T1: introduction in electromobility", "T3: charging systems", "T5: electrical hazard", or "T8: scenarios at accident sites". The duration of the video material of all eight topics is approximately 100 minutes. After every topic, the participants must carry out an interim test (IT), which includes multiple-choice questions. The order of the answers varies at each run to increase the difficulty. At the end of the eighth topic (T8), the participants must pass a final test (FT). At this point it has to be noted, that this is not the final version of the e-learning platform and the development is an iterative process. More information about the training program are available at [4], [6] and [7].

III. Framework of the Test Phase

The evaluation and assessment of the e-learning platform were part of a test phase during the research project "EmoTal" with 120 participants and was performed in April 2017. 31 of the participants are German firefighters and 89 are students at the University of Wuppertal. The results of the students are important for the development of e-learning content (e.g. interactive measurement) for the course "E-Mobility" at the University of Wuppertal. More information about the participants are shown in chapter V.

The main goal of the test phase is the optimization of the current training program and the presentation of recommendations for future training programs with regard to EVs. In the context of the growing spread of EVs and of the great training needs (see chapter I), recommendations and the presentation of experiences are important to handle the new challenges in the education sector.

For the performance of the test phase, the following conditions were defined: The participants have the opportunity to retry the IT unlimited to overcome the pass mark of 75%. In addition, the FT contains 16 exercises and the pass mark is 75% as well. The FT can only be retried three times and the overall time limit for the FT is 45 minutes.

IV. Evaluation Model

The continuous monitoring and evaluation of the quality of the e-learning platform is very important for a successful and sustainable knowledge transfer. Hence, the project team developed a novel evaluation model, see Fig. 2. This iterative model includes a predictive evaluation, a formative evaluation, a summative evaluation, and a post training evaluation.

The goal of the predictive evaluation is the reducing of economic risks for the industrial partner "TÜV" by the detection of potential errors or weaknesses before the training program is launched. The predictive evaluation was realized at the University of Wuppertal and different German fire departments. The participants are German firefighters as well as engineering students. The next step of the evaluation model is the continuous evaluation during the performance of the final training program of the main target groups (firefighters, motor mechanics etc.). This step includes the so-called formative evaluation and summative evaluation [22], [23]. The formative evaluation will be done while the users participate in the training program (e.g. after each topic). Compared to this, the summative evaluation will be performed after the participants have finished the completely training program. In the context of the increasing sales volume of EVs and the further development of new components for EVs the post training evaluation is very useful to get a continuous feedback and thus, to guarantee a continuous optimization. It is e.g. very important to get information about, whether the learning material is a valuable and sufficient preparation for the everyday working life as well as for the rapidly developing automotive sector.

For a better performance of the test phase, a handbook with all necessary information was provided on the e-learning platform. This handbook contains e.g. screenshots with information about the menu navigation or a detailed description for the handling of the interactive measurements.

In this paper, solely the results of the predictive evaluation are shown. The findings of the further evaluation steps (e.g. continuous evaluation) will be content of upcoming papers.

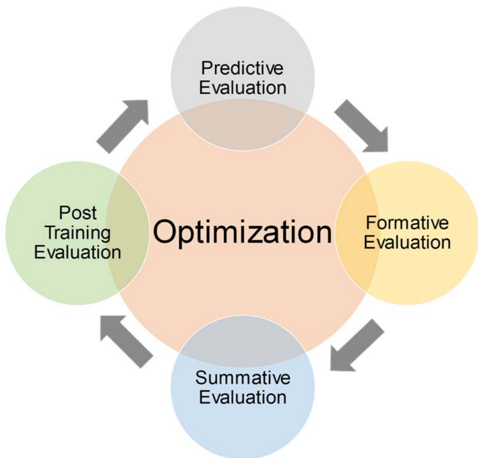

Fig.2. Evaluation model

TABLE I. TOPIC "PERSONAL DETAILS"

	Gender		Age			
Test group	***Female***	***Male***	***Arithmetic mean***	***Median***	***Minimum***	***Maximum***
Firefighters (n=31)	1	30	37.16	38.00	20.00	50.00
Students (n=89)	11	78	25.34	25.00	18.00	51.00

V. EVALUATION RESULTS

The evaluation and assessment of the e-learning platform were performed by an online survey at the end of the training program. The online survey for the firefighters includes 21 questions and for the students 22 questions. This is based on the fact, that the training course for the students possesses interactive measurements at an EV in comparison to the course for the firefighters. Hence, one question serves for the assessment of this exercise. The several questions can be mainly divided into the following five topics: "personal details", "qualification level", "knowledge of electrical engineering", "assessment of the training program", and "personal opinion". The results of the different thematic blocks are illustrated in the following. In addition, an important detail for the interpretation of the presented tables is the meaning of the abbreviation "n", which stands for the number of participants, see e.g. Tab. I.

An interesting finding is the high willingness for the participation in the presented training program. Thirty-one of the 49 registered firefighters (approx. 63%) finished the training program until the end of the test phase. In addition, 89 of the 101 registered students (approx. 88%) finished the training program during the test phase. With regard to the fact, that the participation was voluntary, this result underlines the great interest for the topic E-Mobility respectively the current training needs. Only one of the interviewed firefighters are female and 30 firefighters is male, see Tab. I. The arithmetic mean of the age of the firefighters is 37.16 years, the youngest firefighter is 20 years old, and the oldest firefighter is 50 years old. Compared to the firefighters, 11 female students and 78 male students were interviewed. Furthermore, the arithmetic mean of the age of the students is 25.34 and thus, approximately 12 years under than the arithmetic mean of the firefighters. The oldest student is 51 years old and the youngest student 18 years old.

TABLE II. TOPIC "QUALIFICATION LEVEL"

Firefighters (n=31)	
Main occupation	*%*
Technical 1 (with electrical engineering)	29.03
Technical 2 (without electrical engineering)	25.81
Nontechnical	45.16
Final degree	*%*
General certificate of secundary school	58.06
Final secondary-school examination	25.81
Advanced technical college entrance qualification	16.13
Students (n=89)	
Degree program	*%*
Bachelor "electrical engineering"	16.85
Bachelor "business administration/engineering"	24.72
Master "electrical engineering"	22.47
Master "business administration/engineering"	32.58
Other degree program	3.37
Target degree	*%*
Bachelor	37.08
Master	62.92

As shown in Tab. II, the majority (45.16%) of the interviewed firefighters have a nontechnical main occupation and only 29.03% have a technical occupation with an electrotechnical background. At this point it has to be stated, that most of the German firefighters as well as American firefighters are volunteer firefighters [24], [25]. This finding has to be taken into account during the development process of the training program, because of the different prior knowledge. An adaptive e-learning platform, like [4], could be a good solution to handle the different prior knowledge. Additionally, the last obtained degree of more than half of the interviewed firefighters (58.06%) is the general certificate of secondary school and the rest of the interviewed firefighters have a necessary entrance qualification to study at a university. More than half of the interviewed students (57.3%) are studying "business administration and electrical engineering", which is a combination of engineering and economics. Moreover, 55.05% of the interviewed students are currently studying in a master program. In addition, 62.92% of the students are striving to get a master degree at the end of their academic career. These results emphasize the high motivation of the students and their high willingness to learn.

A further relevant information is the level of knowledge of the participants for electrotechnical topics. Based on this information, a reliable statement is possible, whether a correlation between the level of knowledge and e.g. the assessment of the scope of the learning content exists. The participants had the opportunity to evaluate their level of knowledge based on the German grading scale ("1"=very good; "6"=insufficient). Only 9.68% of the firefighters and 4.49% of the students stated their knowledge as very good, see Tab. III. The most participants of both groups assessed their level of knowledge for electrotechnical topics as good ("2") respectively satisfactory ("3"). However, Tab III. shows that the level of knowledge for electrotechnical topics of the firefighters are lower compared to the students. Thus, the next sections clarify, among other, whether the prior knowledge has a great influence on the satisfaction of the participants.

Tab. IV presents selected results of the assessment of the complete training program. As already mentioned, the

TABLE III. TOPIC "KNOWLEDGE OF ELECTRICAL ENGINEERING"

Value	Firefighters (n=31) [%]	Students (n=89) [%]
1	9.68	4.49
2	29.03	48.31
3	25.81	39.33
4	22.58	4.49
5	12.90	3.37
6	0.00	0.00

TABLE IV. TOPIC "ASSESMENT OF THE TRAINING PROGRAM"

	Firefighters			Students		
Topic	*n*	*Arithmetic mean*	*Standard deviation*	*n*	*Arithmethic mean*	*Standard deviation*
Presentation of the content	31	1.74	0.73	89	1.63	0.70
Difficulty of the questions	31	2.10	0.70	89	1.99	0.87
Learning content is target-oriented	31	2.16	0.86	89	1.81	0.62
User-friendliness: training program	31	2.13	0.88	89	1.71	0.91
User-friendliness: interactive exercises	-	-	-	89	2.48	1.24
Practical relevance: interactive exercises	-	-	-	89	2.02	0.75

interactive exercises were only provided to the students. Therefore, the last two lines of the firefighters' test results are empty, see Tab. IV. The scale of all answers is from very good to very bad and the distance between the several answers is always the same. The participants of both test groups are very satisfied with the presentation of the content (e.g. videos or animations), as can be seen in Tab. IV. With regard to this question, the arithmetic mean of the firefighters is 1.74 and the standard deviation is 0.73. In addition, the arithmetic mean of the students is 1.63 and the standard deviation is 0.70. The difficulty of the questions was evaluated as "good" (2.10 and 1.99). A further interesting question is, whether the learning content is target-oriented or not. At this question, a great deviation between the two test groups can be clearly seen. The arithmetic mean of the firefighters is 2.16 with a standard deviation of 0.86 and the arithmetic mean of the students is 1.81 with a standard deviation of 0.62. Furthermore, the general feedback and the recommendations of the participants (see Tab. V) underline the finding, that the current learning content need to be adjusted in the context of the learning goal of firefighters. For example, one firefighter highlights that the training program needs more tactical details and less electrical details, see Tab. V. Moreover, both, firefighters and students, would like to have more exercises with a practical orientation. The integration of video material, which shows e.g. a burning high-voltage battery and necessary work steps to handle the fire are a promising approach. This approach was underlined by one firefighter, who stated that more videos of rescue measures are desirable, see Tab V. The user-friendliness of the completely training program was evaluated as "good" (2.13 and 1.71), see Tab IV. The evaluation results of the students are better compared to the results of the firefighters. This based most likely on the fact, that the used learn management system (LMS), "ILIAS", is similar to the utilized LMS, "Moodle", at the University of Wuppertal. As already mentioned before and as can be seen in Tab. IV and Tab. V, practical exercises are welcome. Hence, the integration of interactive exercises, which are practical-oriented, is a promising solution to give a realistic insight. Nevertheless, the current interactive measurements need to be optimized, especially with regard to the user-friendless, see Tab. IV. The arithmetic mean of the user-friendliness of the interactive exercises is 2.48 with a high standard deviation of 1.24. This means on the one hand, a great number of students are satisfied with the exercises and on the other hand, many students stated that the interactive measurement has a high optimization potential. The identification of the reasons for the great standard deviation is part of further investigations during the project "EmoTal". A further finding, which underlines the willingness to participate in specialized training programs, is e.g. the active processing time of the users. The users e.g. still participated in the training program, although they have already finished the final test. Moreover, the students recommend the enhancement of the learning content (see Tab. V) and the integration of the e-learning platform in an existing degree program.

VI. CONCLUSION

This paper presents the assessment results of a novel training program for the qualification for working on EVs. The participants of the test phase are 31 firefighters and 89 students. Both groups have shown a great willingness to participate in this training program. Moreover, the results deliver helpful information to improve the training program. Firefighters prefer especially videos, which show e.g. rescue measures at accident sides. In addition, they prefer the integration of more practical exercises and tactical content. Hence, a blended learning concept can be a promising solution. The students prefer the integration of e-learning content in their degree program and they emphasize that interactive exercises are a good preparation for practical exercises as well as for their future working life. Furthermore, the results show that the prior knowledge of the users is, among others, deciding for the user satisfaction respectively for the learning result. Therefore, the development of an adaptive e-learning platform can be a promising approach, especially in the context of the great number of occupational groups with different prior knowledge, which can get in contact with EVs in their everyday working life.

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TABLE V. TOPIC "PERSONAL OPINION"

General feedback		Recommendations	
Firefighters	*Students*	*Firefighters*	*Students*
"Important facts are often repeated…"	"Presentation is very good…"	"More tactical details for firefighters…"	"Enhancement of the learning content…"
"Sound volume is different …"	"Problem with the browser…"	"More videos of rescue measures…"	"A print version would be helpful…"
"Calculations are not so interesting…"	"Training content is too easy…"	"Optimization of the menu navigation…"	"Increase the difficulty…"
"Too much technical details…"	"Good insight in the topic E-Mobility…"	"Add more practical exercises…"	"More practical exercises…"
"Very good and detailed presentation…"	"Interactive measurements are good…"	"Less electrical details…"	"More interactive measurements…"

REFERENCES

[1] International Energy Agency, "Global EV Outlook 2016," Paris, 2016.

[2] Kultusministerkonferenz, „Rahmenlehrplan für den Ausbildungsberuf Kraftfahrzeugmechatroniker und Kraftfahrzeugmechtaronikerin,“ KMK, 2013.

[3] EmoTal, "EmoTal – User Centred Electric Mobility Wuppertal,". Available: https://www.emotal.de/. [Accessed: April 10, 2017].

[4] H. Fechtner, K.-H. Saes and B. Schmuelling, “An adaptive e-learning platform for the qualification for working on electric vehicles,” in *IEEE Frontiers in Education 2016*, Erie, USA, 2016.

[5] California Center for Sutainable Energy & California Clean Cities Coalitions, "Needs Assessment for Alternative Fuel Vehicle Training in California," San Diego, USA, 2013.

[6] H. Fechtner, E. Fechtner, B. Schmuelling and K.-H. Saes, "A new challenge for the training sector: Further education for working on electric vehicles," in *IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE) 2015*, Zhuhai, China, 2015.

[7] H. Fechtner, K.-H. Saes, E. Fechtner, T. Braun and B. Schmuelling, "Clarification of the Training Requirements for Working on Electric Vehicles," *International Journal of Advanced Corporate Learning,* vol. 9, no. 1, pp. 35-43, 2016.

[8] A. Bouscayrol and P. Delarue, "Project-based Master on Intelligent Electric Vehicles," in *IEEE Vehicle Power and Propulsion Conference*, Hangzhou, China, 2016.

[9] P. Fajri, N. Lotfi, M. Ferdowski and R. G. Landers, "Development of an Educational Small-Sclae Hybrid Electric Vehicle (HEV) setup," *IEEE Intelligent Transportation Systems Magazine,* vol. 8, pp. 8-21, 2016.

[10] National Fire Protection Association, "Alternative Fuel Vehicles Safety Training Program,". Available: http://www.evsafetytraining.org/. [Accessed: April 25, 2017].

[11] National Alternative Fuels Training Consortium & West Virgina University, "Advanced Electric Drive Vehicle Education Program,". Available: http://www.aedve.info/. [Accessed: April 25, 2017].

[12] M. Huba and V. Ferencey, "New challenges in e-mobility education for Slovakia," in *13th International Conference on Emerging eLearning Technologies and Applications*, Starý Smokovec, Slovakia, 2015.

[13] A. G. Picciano, "Blended Learning: Impacts for Growth and Access," *Journal of asynchronous learning networks,* pp. 95-102, 01 2006.

[14] A. G. Picciano, Blended Learning, New York, USA: Routledge , 2014.

[15] M. Tayebinik and M. Puteh, "Blended Learning or E-learning?," *IMCAST,* pp. 103-110, 1 02 2015.

[16] B. Akkoyunlu and M. Y. Soylu, "A Study of Student’s Perceptions in a Blended Learning Environment Based on Different Learning Styles," *Educational Technology & Society,* pp. 183-193, 2008.

[17] E. T. Welsh, C. R. Wanberg, K. G. Brown and M. J. Simmering, "E-learning: emerging uses, empirical results and future directions," *International Journal of Training and Development,* vol. 7, no. 4, pp. 245-258, 2003.

[18] T. Horvat, T. Alajbeg and S. Predanic, "Experiences and Practices in Blended Learning Environment," in *IEEE 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO) 2015* , Opatija, Croatia, 2015.

[19] J. A. Méndez and E. J. González, "Implementing Motivational Features in Reactive Blended Learning: Application to an Introductory Control Engineering Course," *IEEE Transaction on Education,* vol. 54, no. 4, pp. 619-627, 2011.

[20] I. H. Mohd, A. H. Aluwi, N. Hussein and M. K. Omar, "Enhancing Students Engagement through Blended Learning Satisfaction and Lecturer Support," in *IEEE 8th International Conference on Engineering Education* , Kuala Lumpur, Malaysia, 2016.

[21] Deutsche Gesetzliche Unfallversicherung, "DGUV Information 200-006 – Training for work on vehicles with high voltage systems," Berlin, Germany, 2012.

[22] A. A. Adline and G. S. Mahalakshmi, " A novel framework for E-learning content evaluation," in *IEEE ICoAC* , Chennai, India, 2011.

[23] U.-D. Ehlers and J. M. Pawlowski, Handbook on Quality and Standardisation in E-Learning, Springer, 2006.

[24] Deutscher Feuerwehr Verband, "Feuerwehr-Statistik,". Available: http://www.feuerwehrverband.de/statistik.html. [Accessed: April 26, 2017].

[25] National Fire Protection Association, "U.S. fire department profile,". Available: http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/administration/us-fire-department-profile. [Accessed: April 26, 2017].