Empirical and Iterative Evaluation Model for the Development of E-learning Content for Freshmen of Electrical Engineering Degree Programs

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***Abstract*—This research-to-practice work in progress paper shows an empirical and iterative evaluation model to improve e-learning content for freshmen. The application of the evaluation model makes, among others, the consideration of students' feedback feasible. The survey results presented in this paper underlines the importance of this feedback regarding the optimization of learning content. A further highlight of this paper is the introduction of e-learning content, which is integrated in a blended learning concept for freshmen of an electrical engineering degree program. Interactive exercises are one part of the developed e-learning content and can be applied for the preparation of practical exercises, which are also part of the blended learning concept. Finally, the paper gives recommendations based on gained experience.**

***Keywords*—e-learning, freshman, education, engineering, evaluation model, blended learning**

I. Introduction

E-learning can be a powerful tool for the enhancement of knowledge transfer and delivers advantages for the different types of learning (visual, auditory etc.). Nowadays, the wide spread of mobile devices offers the opportunity to share knowledge in real-time. The integration of e-learning content into academic teaching is a logical conclusion of this technological development.

The first steps at the university can be a challenge for freshman. Hence, the necessary support can be realized by e-learning content. In addition, freshmen have problems to transfer the contents learned into practice. Therefore, video-tutorials for the preparation of practical exercises (e.g. correct use of a multimeter) and the presentation of hints for a more efficient learning strategy can be a promising solution to increase the knowledge transfer and the students´ motivation. In upcoming chapters, the necessity, advantages, challenges, and benefits of e-learning for academic teaching are shown.

A. Advantages and Challenges of E-learning

E-learning has different advantages compared to conventional learning. One of the major advantages is the great accessibility and the flexibility in learning [1]. In [2] and [3], the authors emphasized that students have a positive attitude towards e-learning and using mobile devices for education. In addition, teachers have a great opportunity to integrate different learning strategies and to provide additional information. For an efficient knowledge transfer, state of knowledge, guideline, and learning objective should be addressed at the beginning of every online lesson. However, the most important parameters for a successful e-learning process is the motivation and discipline of the students [4]. Hence, the students need to be motivated by the created e-learning course. For example, some e-learning courses try to motivate the students by introducing a reward system [5].

Engineering degree programs have a wide range of different sciences and various research fields, methods, and applications. By the use of different didactic approaches, e-learning can be a successfully tool for education in the field of engineering. Nevertheless, different topics need different methods to secure a transfer of knowledge [6]. Thus, a blended learning concept is a didactic method with a great potential for engineering degree programs. Furthermore, e-learning or rather distanced learning lead to less experience in laboratory work. In the field of engineering, it is essential to get experience in practical applications [1], [7]. Hence, this challenge can be overcome by blended learning.

B. Research Objective

On the one hand, e-learning has many advantages like availability at every time and from every location with internet access. For example, this benefit can be one of the key factors to handle knowledge transfer at schools, colleges, and universities during the corona pandemic, which started at the beginning of 2020. On the other hand, one of the major challenges of e-learning is to motivate participants over the whole usage. In addition, the self-learning process can be enhanced by motivation. As a result, the knowledge transfer can be increased as well. Hence, the research object is to integrate an evaluation tool into a blended learning concept. This approach makes the consideration of the students' needs and wishes feasible. Furthermore, the continuously feedback

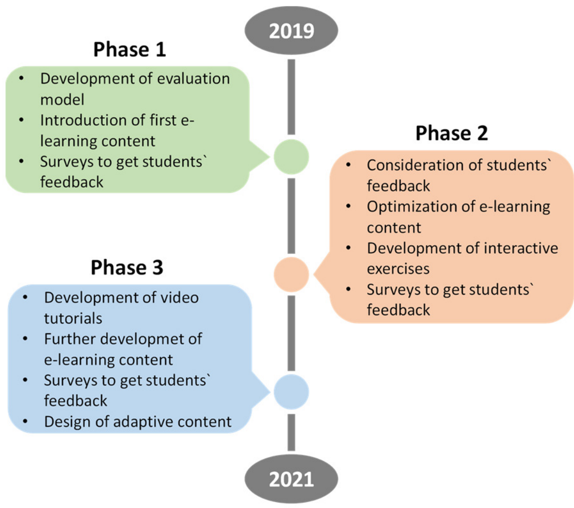

Fig. 1. Timeline of the e-learning project

of the students helps to develop more user-friendly e-learning content. Therefore, the overall research objective is to analyze the impact of the developed evaluation model on students' motivation.

The work in progress paper gives a good insight in the current state of the blended learning concept and shows the first results of experience gained by the introduction of the evaluation model. Thus, this paper includes the results of the first development phase (see Fig. 1). The next steps are e.g. the optimization of the e-learning content based on students´ feedback as well as the realization of interactive exercises, as you can see in Fig. 1. In summer 2021, the development of the e-learning content of the blended learning concept shall be finalized. Nevertheless, feedback of the students will be considered each semester. More information about this goal are presented in chapter III.

A further goal of this work is to support students in their own learning behavior, to make asynchronous learning feasible, and let students decide which workplace and environment they prefer.

II. Applied Blended Learning Concept

Every didactical methodology has advantages and disadvantages. The effectiveness of the applied methods depends, among others, on current knowledge level of the students as well as on the different types of learners (tactile, visual, auditory etc.). The authors of [8] summarize that the consideration of the different types of learners is important for a successful outcome of learning programs. Due to this finding, they recommend e.g. an adaptive structure to handle the different learning styles, which the several students prefer. In phase 3 of the project, see Fig. 1, the integration of adaptive content based on e.g. students' knowledge level is planned.

In [9] and [10], authors emphasized that blended learning is a promising tool to improve e.g. the student engagement in engineering courses. As a result, our approach is to combine the weaknesses and strengths of each method. Therefore, the developed e-learning content is integrated in a blended learning concept that is shown in Fig. 2. The next chapter highlights the different methodological approaches as well as current e-learning content.

A. Concept Presentation

The current e-learning course is one part of the blended learning concept. The concept is developed for the course "principles of electrical engineering 1" at University of

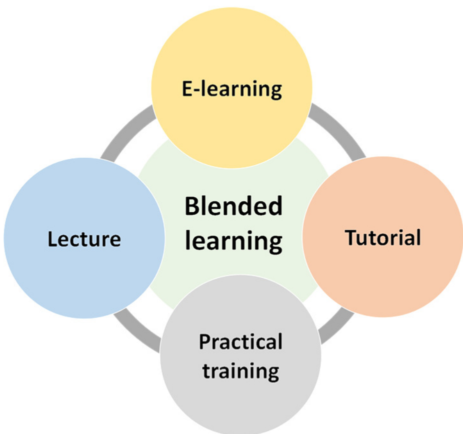

Fig. 2. Applied blended learning concept

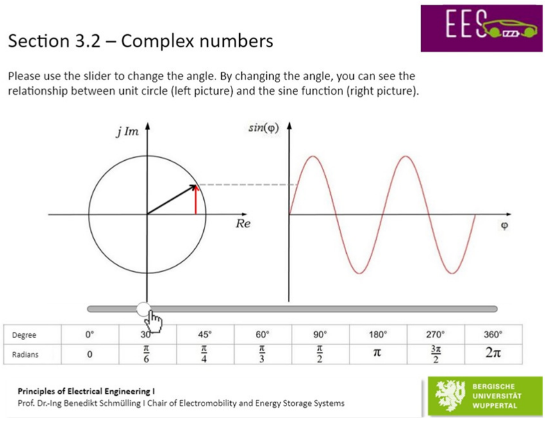

Fig. 3. Complex numbers and unit circle in context of alternating voltage

Wuppertal (Germany) and contains lectures, tutorials, e-learning, and practical training at a laboratory. Practical training at laboratory are important for engineering students. This can be underlined e.g. by the findings of [11]. The authors emphasized that students have problems to transfer theoretical knowledge into practice applications in engineering. Therefore, by practical exercises especially freshmen get their first experience in dealing e.g. with measuring instruments.

B. E-learning Content

It is important to know that the current e-learning course is a preliminary version and is only used to get first experience in online courses for freshmen and to realize a predictive evaluation (see chapter III). The current content can be divided into three main categories. The first category contains conventional exercises like quizzes and tasks to solve mathematical problems. Fig. 3 illustrates e.g. theoretical knowledge of complex numbers. This topic is indispensable in the context of alternating current. The students are able to change the angle by sliding the button. Hence, students can get a better understanding for the phase angle of alternating current and voltage. The aim of this category is, among others, to encourage and prepare students for upcoming exams.

The second part possesses interactive exercises to use theoretical knowledge for the realization of basic electrical circuits. In Fig. 4, one of the interactive exercises is shown. For example, the students are able to move the electrical components (e.g. LED, resistance). Further features are the opportunity to change the measuring range and to change the position of the test prod by moving the cursor.

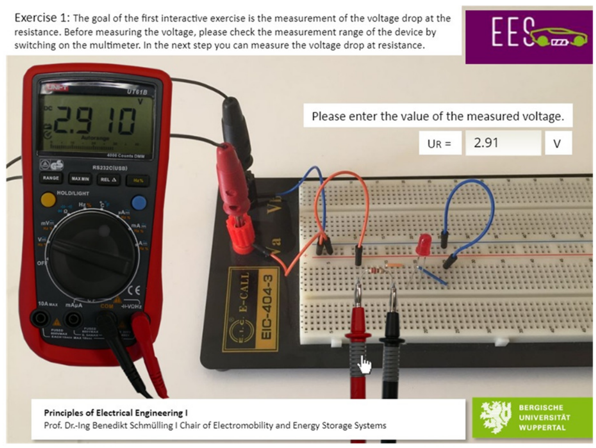

Fig. 4. Interactive exercise at a breadboard

In addition, the third part includes interactive exercises to prepare students for practical exercises at the laboratory. For example, students learn to handle common devices (e.g. power supply unit, oscilloscope). Training for dealing with electrical devices is an important topic for freshmen regarding their motivation. Moreover, if students are well prepared, the practical exercises could be more efficient and thus, the learning effect is higher.

III. Empirical and Iterative Evaluation Model

One key factor for the realization of a successful e-learning program is the evaluation of the effectiveness of the program [12]. Regarding the increasing number of e-learning programs, the topic "evaluation" gets more popular. Thus, the improvement of current evaluation methods is appreciated to take e.g. new e-learning trends into account [12]. For example, in [13] the authors highlight the benefits of analyzing students' learning process regarding game elements for programming education. In addition, further projects [12] use evaluation tools to optimize and enhance their didactic methods as well as learning content.

Hence, previous publications show the importance of evaluation processes to identify e.g. weaknesses. For the consideration of the needs of freshmen during the development process of e-learning content, the developed empirical and iterative evaluation model is used. One of the major benefits of this iterative approach compared to common evaluation tools is the continuous evaluation.

A. Evaluation Model

The applied evaluation model is a further development of an evaluation tool that was development by our research group in 2017 in the context of electric vehicles [14]. The evaluation model composed the predictive, formative, and summative evaluation for a continuous optimization of the e-learning content, as you can see in Fig. 5. For the identification of the students´ needs and wishes, the predictive evaluation is the first step of the used evaluation model and needs to be realized before the e-learning content is fully developed. The further evaluation steps will be implemented during (formative) and after (summative) the students use the e-learning content.

The first predictive evaluation has been done in January 2020 with 52 students of the course "principles of electrical engineering 1" and delivers helpful information for further development of the e-learning content (e.g. preparation for practical exercises). More information about the results of the first predictive evaluation are presented and discussed in chapter IV.

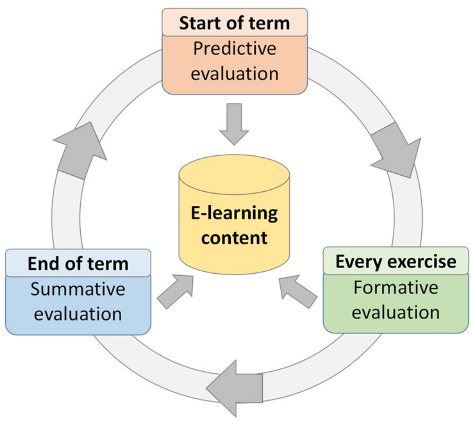

Fig. 5. Applied empirical and iterative evaluation model

B. Benefits for Academic Teaching

The implementation of the evaluation model into academic teaching is one of the main goals of our project. The focus of this approach is on the optimization of the course "principles of electrical engineering 1". This course is one of the major lectures for freshmen and provides the basic knowledge of prospective electrical engineers. Teaching freshmen can be a challenge for teachers depending on the different previous education of the students. For example, some of the students have already finished a qualification as an electrician or a mechanic. Hence, the knowledge level of the student varies and depends on their school and vocational training. Therefore, a continuous collection of students' feedback is indispensable to consider changes in school and vocational education, which, among others, based on school policy changes. Especially the knowledge level of freshmen is not a constant parameter. Thus, the designed evaluation tool can consider annual changes of the knowledge level of freshmen.

The empirical and iterative evaluation model presented in Fig. 5 is a promising approach to achieve the above-mentioned objectives. To secure a constructive development process, a continuous evaluation of students need is a helpful tool. As a result, students get e.g. necessary support to solve problems and to understand theoretical methods [6].

IV. Results and Discussion

The introduced evaluation model has three different evaluation steps. One of the three evaluation methods is the predictive evaluation. In context of the current state of the e-learning course, see chapter II, the results of the first predictive evaluation are relevant to optimize the current content as well as to develop further content based on students' feedback. The first results are presented in upcoming chapters.

A. Survey Results

Goal of the first predictive evaluation is e.g. to understand the problems and needs of freshmen and to assess their knowledge level. Therefore, the survey includes the following categories: current knowledge level, experience in using e-learning content, improvement suggestions for current e-learning content, effectiveness of the preliminary version of the e-learning course, and wishes for upcoming content.

Fifty-two students (male: 43; female: 9) have participated in the survey, which was done in January 2020. Approximately 77% of the students have already gained experience on dealing with e-learning content. Only 52% of the freshmen use e-learning content in other courses at the university. This means, the students have already get in contact with e-learning at their previous school education. In addition, 16 of the 52 students have not used the e-learning content. The majority of the students (42) have stated that the e-learning content helps to get a better understanding for the theoretical content presented in lecture. The extension of the current e-learning content is welcomed by 94% of the students.

As presented in Fig. 6, the students are interested in video-tutorials, interactive exercises, multiple-choice questions, and mathematical content. It can be identified that the students prefer video-tutorials and are interested in the solution of mathematical tasks. Based on this result, in development step 3 of the project, see Fig. 1, the design and realization of video-tutorials is one of the major tasks. As stated before, practical

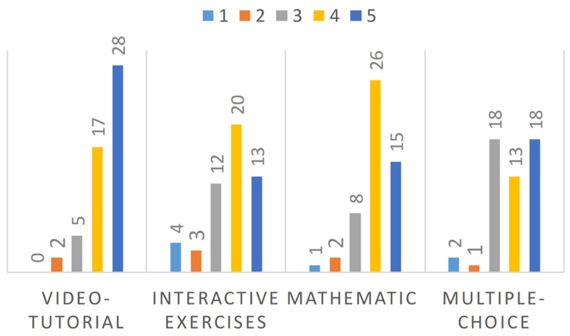

Fig. 6. Assessment of different types of exercises. 1: low importance; 5: great importance

exercises are important for engineering students and especially for freshmen. To increase the satisfaction of the students as well as to enhance the effectiveness of practical exercises, further interactive exercises and video-tutorials will be introduced. The survey results in Fig. 7 underline this approach.

B. Analysis of User Behavior

Continuous analysis of the user behavior is important to optimize e-learning content and graphical user interface, respectively. The design of e-learning courses is important with regard to participants' satisfaction [10]. In addition, the obtained information can be used to develop a more user-friendly e-learning course and to detect correlation between the surveys results and actual user behavior. Regarding the focus of this paper, the aim of this short analysis is to detect weaknesses of the first e-learning content as well as to investigate the motivation of the students.

The current version of the e-learning course contains, among others, seven exercises. As shown in Fig. 8, it can be stated that the participation of the students clearly decrease. At beginning of the course, 141 of 299 registered students have participated in exercise 1. Compared to exercise 1, only 36 students have used exercise 7 to improve their knowledge in principles of electrical engineering.

The current exercises have been developed especially for the exam preparation. The exam was planned for the end of March 2020. Due to the corona pandemic, the exam has been canceled. Based on our assessment, the cancellation of the exam is the main reason for the low participation. Hence, the realization of a detailed analysis of the user behavior is not feasible. Nevertheless, this result shows that the exam preparation has a great influence on students' motivation. In upcoming work, a further goal is to analyze common

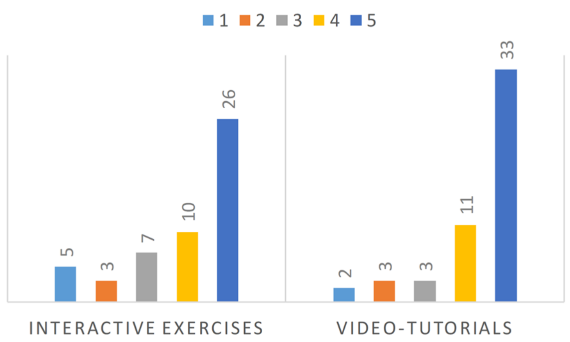

Fig. 7. Relevance for the preparation of practical exercises at laboratory. 1: low relevance; 5: great relevance

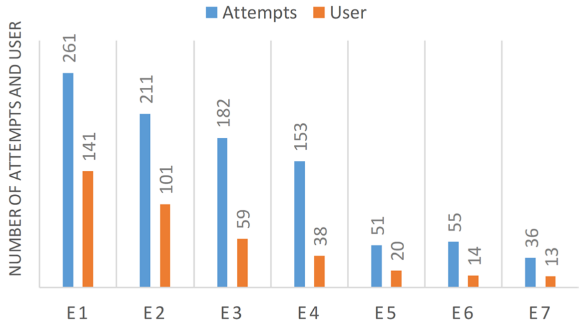

Fig. 8. Number of attempts and users for each exercise (E)

motivation strategies in detail to enhance intrinsic and extrinsic motivation, like [15].

A further result of the analysis is that students have many problems to solve computational exercises without hints. During the semester, the students contacted the lecture via e-mail and further communication channels like face-to-face communication. Therefore, one of the upcoming updates of the e-learning course contains the presentation of solution approaches. This point is important in the context of freshman. By the presentation of hints and solutions, it is possible to increase the motivation of freshmen.

V. Conclusion and Future Work

E-learning has great potential to increase the knowledge transfer and to consider different types of learners. The great accessibility is a further advantage and can be an effective learning tool during semester break or global pandemics, like the current corona pandemic. On the other hand, e-learning has some challenges that need to be overcome. For example, students need self-discipline and the e-learning content have to be attractive regarding students' motivation. The developed e-learning content is part of a blended learning concept. Further publications underline the opportunity to optimize the learning process by blended learning. In addition, practical exercises are important for engineering students and especially for freshmen.

To achieve these goals, the presented evaluation model has the potential to improve the effectiveness of the e-learning courses "principles of electrical engineering 1" by an iterative approach. The results of the first predictive analysis shows that the majority of the students are very interested in video-tutorials and interactive exercises. These types of exercises have the advantage to prepare students for practical exercises at laboratory. Hence, a more efficient realization of practical exercises as well as an improvement of knowledge transfer are feasible. The analysis results of the user behavior underline the importance of student's motivation. At the beginning of the course, a great number of students have used the e-learning content to enhance their knowledge. Compared to this, the utilization rate decreased at the following exercises.

In future work, a detailed mathematical statistical analysis of the user behavior will be publicized. Additionally, a comparison between the benefits of the presented approach compared to traditional teaching is planned for 2021. The creation of adaptive e-learning content is a further development of the presented project. The adaptive content based on the knowledge level of each student and can be identified e.g. by a pretest. Finally, transferability of the presented model to other disciplines need to be analyzed.

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