ASSESSMENT OF DIGITAL LABORATORY EFFECTIVENESS IN THE BASIC ELECTRONICS SUBJECT

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Abstract

Nowadays electronics is present in every scene of modern life. The ever-increasing relevance of complex systems with low power consumption and small size has been particularly challenging for higher educational institutions. Universities have already included a wide variety of new concepts and knowledge in their contents to fulfill the expectations of our society. COVID-19 pandemic has changed the ways of teaching and learning for both teachers and students, who have had to adapt to this fact accordingly. That is why now it is not only necessary to develop new methodologies to address the transfer of knowledge and skills, but it is also necessary to previously evaluate whether the changes are beneficial or not for the teaching-learning binomial. Online teaching demands time-consuming digital resources to be effective. This requires a careful planning and validation process, with a critical attitude towards the improvements made for a better assimilation of knowledge. This work evaluates the use of the digital laboratory in the Basic Electronics subject, a 2nd year compulsory subject of the Industrial Engineering degree of the University of Almeria in four specialties: Industrial Electronics Engineering, Electrical Engineering, Industrial Chemical Engineering and Mechanical Engineering. The practices methodology in the last four academic years are analyzed: 2018-19 with face-to-face teaching before the pandemic, 2019-20 with some face-to-face teaching and then virtual teaching with digital laboratory support after the pandemic restrictions, 2020-21 with 100% virtual teaching and digital laboratory, and 2021-22 with a hybrid model (face-to-face teaching and digital laboratory). The academic results show that the introduction of the digital laboratory in the practices makes students improve the success rate in them, although it does not affect the success rate of the subject. The academic years where the subject has been taught virtually have a higher rate of absenteeism than those that were face-to-face. Regarding the results of passing students in the practices, it is shown that promoting the use of the digital laboratory not only improves this rate, but also the grades are better. After analyzing the statistics of the last four academic years, it is found that the 2021-22 academic year, when the hybrid practices have been carried out, is the one that has achieved the best results. The analysis also shows that in the field of engineering, a satisfactory compromise between the use of the digital laboratory and face-to-face learning must be reached to prepare students for the changing labor market.

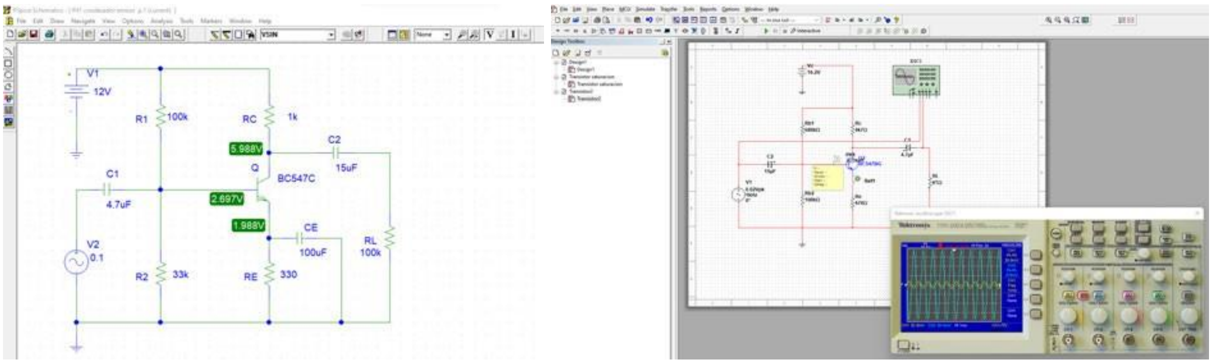
Keywords: Electronics, digital laboratory, COVID-19.

1 INTRODUCTION

Pandemic caused by SARS-CoV-2 set down a milestone in the history of 21st century about how to overcome difficulties in all areas of society: humanitarian, social, labor, educational, etc. [1]. The academic environment was immersed in an unprecedented change as the interruption of face-to-face activities in the universities led to a sudden substitution of the teaching methodology. At that point, universities began to adapt their services and contents to an online format within a very brief period. This involved a significant effort for the entire academic community: teachers had to adapt to the high rate of change; students encountered technical or economic difficulties in accessing online teaching; and universities had to establish adequate, efficient, and reliable online services suited to education. The swift and urgent transformation from face-to-face teaching to an online format was conducted in a way that may seem appropriate and acceptable in overall terms, although the decisions and actions were taken in haste, instead under a planning specifically designed from its inception to teach subjects with a completely online methodology [2]. Educational centers, teachers, and students have faced this issue to establish an emergency response, in which technology has allowed to think that another, more innovative and creative university education is possible [3], although it has not been possible to plan or ensure that all the actors involved had the minimum required technological means, the necessary digital skills, or open attitude to change, among other relevant factors. This emergency situation has revealed and magnified the existence of some gaps [4] such as the access to information (having or not having access to electronic devices and/or internet connection) or related to the time of use and the quality of this, but most importantly, on the digital skills of teachers and students to properly use digital platforms for educational purposes. Apart from these three shortcomings, we must add the problems and implications arising from the online assessment.

Engineering students require conceptual understanding and its practical application to any field of science, solving problems by relating concepts that are not visible to the naked eye. What a good engineer is able to see is encouraged by teachers in the fields of engineering and science in general. That is why engineering areas require a great deal of experimental work. This practical task is carried out in university laboratories, which are specifically designed to attend to different subjects. In the laboratories the students implement the application of the notions explained in the theory classes and they begin to interrelate the different concepts [5]. In the age of digital communications, the limitation of performing the work in a physical laboratory has disappeared [6]. The motivation is to eliminate physical barriers between the experimental work and the students, as well as to expand engineering studies with a distance offer, without giving up the essence of engineering (the experimental part). This raises how to educate in a digital environment where teaching paradigms face a continuous change [7]. Currently there is a wide variety of online tools that allow students to improve their knowledge and/or digital skills, in addition to work in groups. This allows the development of two skills present in all engineering curricula: the use of ICT (Information and Communications Technology) and teamwork.

Currently, there is a wide variety of tools that allow online technical teaching. Among these tools are the digital laboratories that allow a similar laboratory in a digital environment accessible from the Internet. Traditionally simulators have been used for a long time to support teaching in electronics subjects. Simulators with a graphical interface (Figure 1a) were the forerunners of the digital laboratory (Figure 1b), where students can manage and interact with virtual objects and tools, as well as formulate and test alternative hypotheses in a variety of ways [8]. In this regard, the University of Almeria (UAL) has a license for Multisim® [9], a software for analog, digital, and power electronics in education and research. Multisim integrates industry-standard simulation with an interactive schematic environment to instantly visualize and analyze the behavior of electronic circuits. Previous work has shown that the process of teaching by using Multisim improves teaching methods, teaching quality, and cultivates students' practical knowledge [10]. The UAL annually renews the license for this program and teachers provide it to the students each year.



a) *b)*

Figure 1. Electronics software. (a) Simulator; (b) Digital laboratory.

Digital laboratories such as Multisim allow the development of particular engineering skills. The virtual tools can be guided according to the needs of the students (acquisition of complex knowledge, educationally oriented games to skills acquisition, etc.) [11]. Digital laboratories are a common and versatile tool in engineering, which have been adapting to new perspectives and possibilities with the advances in communications. The digital laboratory allows students to have their own laboratory at their fingertips, obtaining measurements, processing data, performing physical analysis, and interacting with other remote devices to share data and results between online users. This fact provides a great advantage over traditional laboratories where the student travels to the university, while the present and future of the university is that the laboratory travels with the student. From the point of view of the higher education area this is a remarkable fact, since education must be focused on the students, in this case with their smart devices.

With the change in educational methodology, these types of tools have been used without regular monitoring. In this paper we have assessed the effectiveness of the introduction of the digital laboratory in the practices of the Basic Electronics subject. The academic results of the last four years have been analyzed in order to determine the effects of the changes made in the way of teaching the practical sessions of a core and transversal subject. In this way, the evaluation of an adequate methodology can help improve the acquisition of knowledge and skills.

2 METHODOLOGY

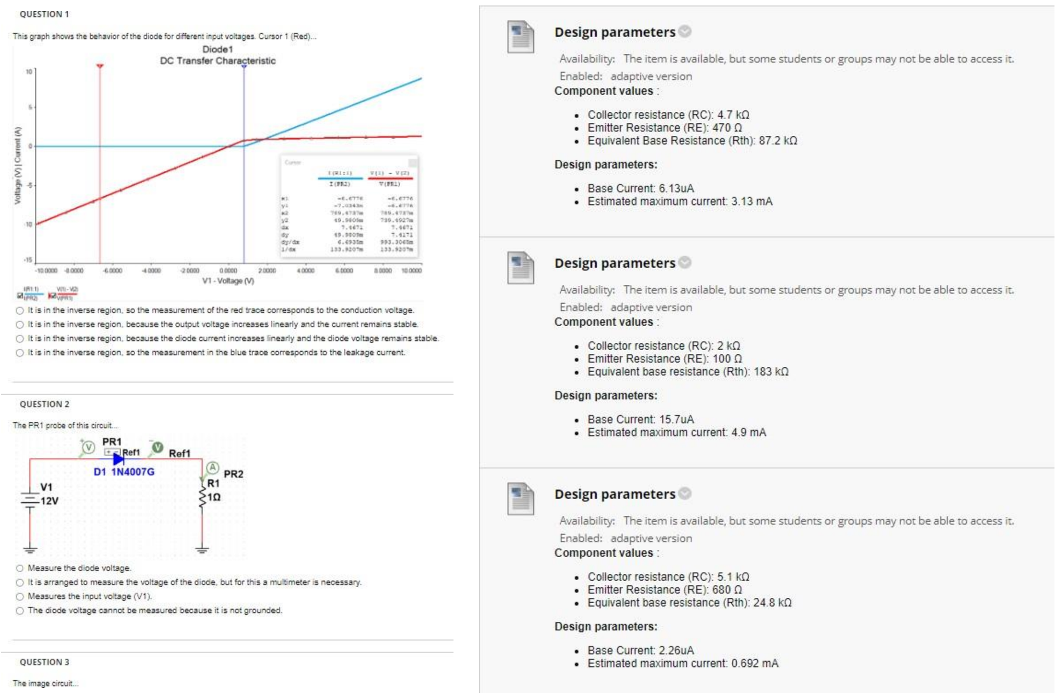
Basic Electronics is a 2^{nd} year compulsory subject of the Industrial Engineering degree of the UAL, and it is taught in four specialties: Industrial Electronics Engineering, Electrical Engineering, Industrial Chemical Engineering and Mechanical Engineering. It is a 6 ECTS subject equivalent to 150 hours, divided into theoretical classes (theory) and practical work (practices), taught in the second semester (from February to May). It is assigned 60 hours for practices, of which 20 are face-to-face laboratory work and the rest is autonomous student work. The length of the practical sessions is 2 hours, and the work is carried out in groups of two students. As the laboratory has a capacity for 15 workstations, the maximum number of students per session is 30.

Until the 2018-2019 academic year, the methodology of the practices consisted of the assembly of different circuits by the students during the laboratory sessions, with the consequent analysis and data collection. Subsequently, as autonomous work, a report of the practical work carried out in the laboratory and the analysis of this using simulators should be made and delivered.

In the 2019-20 academic year the use of Multisim was introduced instead of the simulator. But in March 2020, after two face-to-face sessions, the model became completely online due to the global pandemic. Face-to-face sessions were no longer taught in the laboratories, and to close this gap, the UAL e-learning platform, called Blackboard® [12], was used. Students had to read a document uploaded to Blackboard with the summary of the most important concepts involved in the practice, called "learning module". To strengthen this knowledge, students were proposed to take a test (see Figure 2a), which had to be successfully passed. This self-assessment test could be repeated as many times as necessary until the student successfully passed it. After that, the circuit to be analyzed in the digital laboratory was made visible for the student in the platform, in addition to some parameters that the circuit had to meet, called “design parameters”. Thanks to the knowledge acquired in the learning module, the proposed circuit was analyzed in the digital laboratory until the design parameters given by the teacher were reached. The e-learning platform allows easy customization of the design parameters and circuits for each group of students. Thus, for each of the groups there are different circuits with different parameters (see Figure 2b), which makes copying between groups impossible. To complete the practice, each group had to deliver a screenshot through the platform showing that its circuit complied the proposed specifications. All this work replaced the face-to-face sessions and the report that was traditionally made after data collection in the laboratory sessions.

In the 2020-21 academic years, the situation was the same and the model did not change.

In the 2021-22 academic year it was decided to perform the practices with a hybrid model, combining the virtual assemblies in the digital laboratory with physical assemblies in the laboratory. The traditional methodology was changed taking advantage of all the virtual material that had already been successfully tested during the two years of online teaching due to the pandemic. The novel approach is that before the practical session in the laboratory, students must read the learning module and pass the self-assessment test. The design parameters are then unlocked, and the students analyze the circuit in the digital laboratory until it meets the specifications. All this work replaces the report that was traditionally made after data collection in the laboratory. Thus, when students attend the face-to-face laboratory session, they have already conducted the analysis of the circuit in the digital laboratory and know in advance the results that should come out when they carry out the corresponding measurements, clearing up the uncertainty that they had in many cases about whether their circuit was correctly assembled.



(a) *(b)*

Figure 2. E-learning platform. (a)Example of a question of the self-assessment test; (b) Customized design parameters for each group of students.

The evolution of the distribution of tasks in the practices in the last 4 academic years is shown in Figure 3.

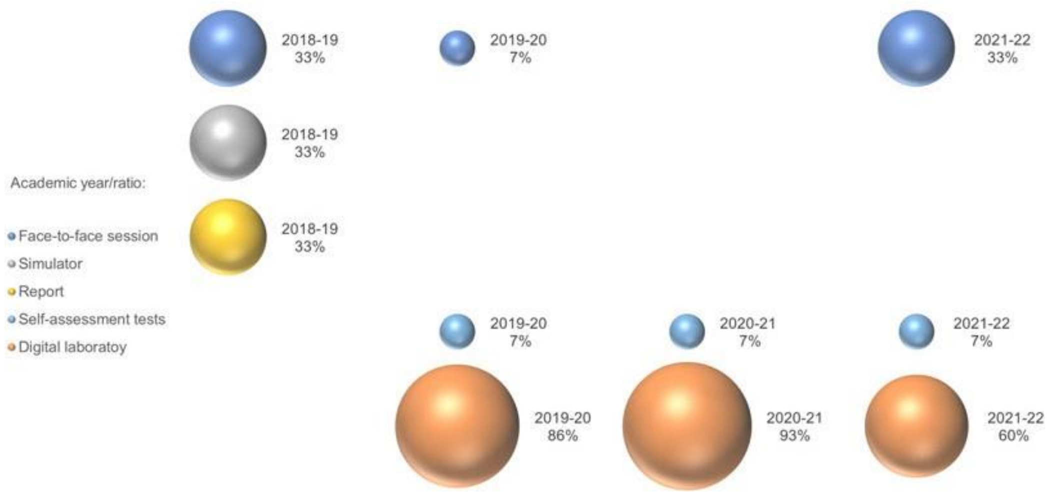


Figure 3. Division of tasks in % in the last 4 academic years.

3 RESULTS AND DISCUSSION

Table 1 presents data of the four last academic years. The number of students enrolled varies depending on the pass rate of the previous year, with approximately the same number of students enrolled in alternate academic years. A correlation is also observed between the pass rate in practices and in theory, with the rate of passing students always higher than in theory. There is no correlation between the rate of failures in practices and in theory, being similar in alternate years, thus the 2019-20 and 2021-22 academic years differ by 2 and 9% respectively and the 2018-19 and 2020-21 academic years differ by 4 and 15% respectively. There is no correlation in the rate of absenteeism in practices and theory, being the 2020-21 academic year (pandemic lockdown) where there is a greater difference value (43% higher than the theory rate).

Table 1. Academic results of the las four academic years.

Year	Students	Practices			Theory		
		Pass	Fail	Absent	Pass	Fail	Absent
2018-19	186	68	43	75	61	35	90
2019-20	138	64	28	46	47	31	60
2020-21	192	108	34	50	55	5	132
2021-22	163	91	27	45	47	41	75

In order to correlate the improvements shown in the practices with the theory, both have been represented in Figure 4 by academic year. Years with face-to-face teaching, the rates in theory are maintained regardless of how the practices were carried out, while absenteeism is higher for the years with online teaching. It can be said that face-to-face learning reduces absenteeism. This indicates that the motivation to learn is higher when students socialize with their classmates and teachers or they are more motivated by different situations [13]. Possible reasons for absenteeism are the technological, pedagogical and social challenges due to the Pandemic. The technology challenges are primarily related to unreliable Internet connections and the lack of necessary electronic devices for many students that can cause student dropout rates. The pedagogical challenges are mainly associated with the lack of digital skills of teachers and students, for example, due to the lack of content, interactivity and motivation of students, and the lack of social and cognitive presence of teachers which discourages the learning process. And finally, the social challenges due to the lack of human interaction between teachers and students, as well as between students and their classmates, the lack of physical spaces at home to receive lessons and the lack of support from parents who often work online in the same spaces. In this work, the reasons that cause absenteeism have not been assessed, although it would be interesting to conduct a study of such reasons. These deficiencies can be addressed through specific online programs, to develop a more active teaching and encourage the participation of students [14], [15].

Among the social aspects highlighted for the students of the 2021-22 academic year is that students do not know each other. These students joined the university without the option of socializing in person and therefore meeting physically. After a year of fully virtual teaching, these students have greater difficulties in teamwork [16]. This is the case of Basic Electronics students since the previous year was completely virtual. The results show that our students value socializing and better solve teamwork skills compared to virtual courses.

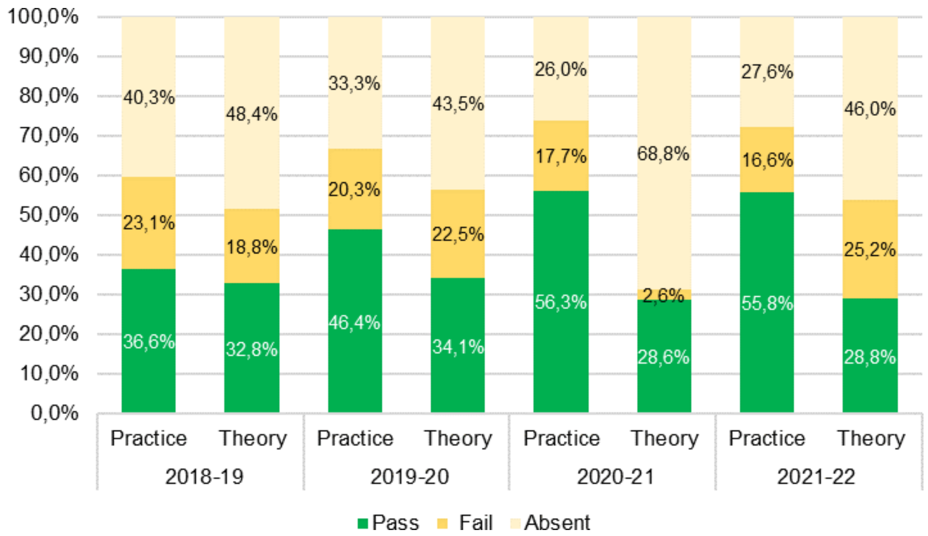


Figure 4. Academic results of the last four academic years in %.

Figure 5 shows the evolution of the practices rates in the academic years assessed. It is found that the pass rate has been improving as the digital laboratory has been incorporated, except for the last year where the values are maintained. The rate of failure and absenteeism has improved with the establishment of the digital laboratory. The results indicate that digital laboratory is widely accepted and demanded by students, who also consider physical laboratories necessary in face-to-face teaching [17], as shown by the results of the 2021-22 academic year.

The passage from the use of simulators to the digital laboratory has been better accepted according to the results of Table 2. In simulators students can test the behavior of electronic circuits, but digital laboratories also incorporate virtual measurement instruments that they will later use in the face-to-face laboratory The incorporation of this type of instruments allows students to carry out better practices in the face-to-face laboratory. This is because the digital laboratory has the same instruments (brand and model) and students are not limited to interacting with them online (in face-to-face teaching they have 20-hours of physical laboratory per academic year). In this way, they can play with them without the fear of breaking them and learn how they work efficiently.

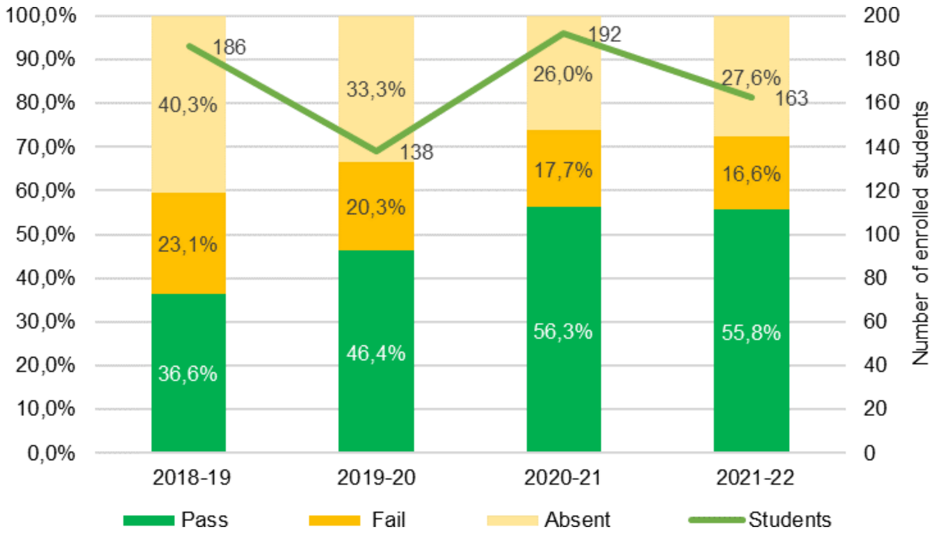


Figure 5. Evolution of the results of the digital laboratory application.

Table 2 shows that the years with face-to-face teaching and digital laboratory obtain better grades.

Table 2. Grades of practices.

Year	***Average mark (score)***		***Grades from 5 to 10 (%)***		
	Pass	***Fail***	***9-10***	***7-8.9***	***5-6.9***
2018-19	5.5	2.4	0	4	96
2019-20	7.7	2.7	19	51	30
2020-21	7.5	2.5	9	61	30
2021-22	7.2	2.1	24	48	27

The way in which students approach practices has changed. Before the 2019-20 academic year, students had to collect data in the laboratory conducting certain measurements and later they had to prepare a report, sometimes extensive. The most frequent problem students faced was that they had not yet fully secure all the concepts in the laboratory session and many times they only realized the mistakes when they had already finished the practical session in the laboratory and were preparing the report at home. Currently, when students attend the face-to-face laboratory session, they have already carried out the analysis of the circuit in the digital laboratory and thanks to the virtual tools they know in advance the results that should come out when they carried out the corresponding measurements in the real oscilloscope in the laboratory session, clearing up the uncertainty that they had in many cases about whether their circuit was correctly assembled.

4 CONCLUSIONS

The changes associated with the adaptations due to COVID-19 pandemic have caused a new way of working in all areas of society, including the academic environment. In the case of the higher educational system, the establishment of an online methodology teaching was the only way to develop quality education during the lockdown period suffered in Europe and the wider world during the years 2019 to 2020. Universities have taken advantage of the digital transformation to enhance the skills and competencies that students must acquire, although the advantages and disadvantages of these changes are not yet known. We have assessed the statistics of our engineering students, in order to determine the changes made in the way of teaching the practical sessions of a core and transversal subject of four engineering specialties, such as Basic Electronics. The evaluation of an adequate methodology can help improve the acquisition of the knowledge and skills, as well as motivate students and reduce absenteeism. Although there are works that show that most of our students appreciate the advantages of digitalization, our results show that this should be a support and not a unique alternative. Digital laboratories are established as a powerful support tool for the right acquisition of professional skills of an industrial engineer. The digital laboratory must be used progressively from the beginning of the degree until reaching a maximum value at the end. Students must be prepared to face the challenges of the professional environment they will find, acquiring specific skills. Thus, an adequate use of the digital laboratory must be established without neglecting the advantages provided by the face-to-face teaching at the traditional laboratory.

The academic results assessed show that the introduction of the digital laboratory in the practices makes the students improve the pass rate, but this success is not transferred to the theory. The academic years where the subject has been taught virtually due to the pandemic have a higher rate of absenteeism than those years with face-to-face teaching. Technological, pedagogical and social challenges due to the pandemic are proposed as possible reasons. It is also found that the incorporation of the use of the digital laboratory not only improves the pass rate, but also the grades are better. In the last academic year when hybrid practices have been carried out, the results were the best. Although future academic outcomes must be widely analyzed, it follows that a compromise must be reached between the use of digital media laboratory and face-to-face learning in the field of engineering, where students must be prepared for the changing requirements of the world of work.

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