Reconnection between theory and practice in a technical course affected by the pandemic

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Abstract

We report on the experience of offering two subjects in a technical course in Electromechanics during the COVID-19 pandemic. The main goal is to analyze the teaching strategies adapted for the subjects of Basic Electronics, using simulators in a remote way and Electronic Drives, offered in a hybrid way, between remote and face-to-face classes, observing the students' engagement in these subjects. To do so, a theoretical reference on the use of simulators was sought, and methodologies were defined for each of the subjects, considering the context of the pandemic. As a result, a comparison of the two subjects offerings and the methodologies used, an analysis of student engagement, and learnings for future work are presented.

Keywords: remote teaching; emergency teaching; COVID-19.

Introduction

In the years 2020 and 2021, teaching activities have undergone an abrupt change due to the need for social isolation to deal with the COVID-19 pandemic. This has affected all levels of education, since students and teachers in general have not been previously prepared for this model of emergency remote teaching (ERT). This model is characterized by the temporary use of the remote format in courses that would otherwise be face-to-face, which can be done through digital platforms (VALENTE; MORAES; SANCHES, 2020), and has been a reality both in Brazil and in other countries, as shown by Bond, Bedenlier, Marín, and Händel (2021). ERT differs from distance learning (DL) because it does have the same level of planning and by not being based on an education model such as DL (VALENTE; MORAES; SANCHES, 2020). As mentioned by Valente (2021), the transition between face-to-face and remote teaching was necessary in order not to generate a disruption in ongoing courses. In particular, technical courses with laboratory activities needed to be completely restructured and the dynamic between theory and practice went through a process of reconfiguration.

During the years 2020 and 2021, the classes of the subsequent technical course in Electromechanics at the Instituto Federal de Santa Catarina (IFSC,) Campus Caçador, were adapted to the ERT format, so that part of the classes were offered remotely and the laboratory classes, essential for the completion of several subjects, were held back. With the return of face-to-face classes in September 2021, these subjects could be completed. The subject of Basic Electronics, specifically, was concluded with practices still remotely, by means of simulators, while the Electronic Drives subject could be concluded with practical classes in the laboratory, both disciplines being offered in close proximity.

One of the ways to strengthen the teaching without the possibility of accessing the laboratories is the use of simulators as a bridge between the remote classes and the practical ones

As a general purpose, this paper presents a comparison between the offering of these two subjects with regard to the engagement of students, their performance, and their involvement in the activities, in order to present an assessment of the experience and also the learnings for future classes.

The specific purposes are: to use simulators appropriately during remote emergency classes; to define specific methodologies for this situation in order to optimize the transition back to face-to-face classes; and to obtain, through this atypical situation, learning related to teaching methodologies that can be used in the future during normal times.

Use of simulators

One of the ways to strengthen the teaching without the possibility of accessing the laboratories is the use of simulators as a bridge between the remote classes (which unfortunately brought a more theoretical focus) and the practical ones, which will be back later. The use of simulators for educational purposes in the field of electricity is not new, being researched, for example, by Hart (1993). In that paper, the author mentions that computer simulation is useful for stimulating learning through visualization of voltage and current waveforms, and can be used in place of, or as a complement to, an experimental lab class.

One of the advantages of simulators is that they can be accessed from any computer with minimal requirements and do not require the presence of a responsible person, as in the case of laboratories (COUTINHO, 2013). Furthermore, as studied by Silva, Santos, and Pelacini (2018), the use of simulators is seen as positive for student engagement and interest in the subject, although they do not exclude the need for face-to-face laboratory experiments.

Simulators also present some challenges, such as how to express a knowledge or situation within the syntax of the program (SUMMIT; RICKARDS, 2013). It is noteworthy that, in addition to simulators, other digital technologies, such as previously recorded video lessons, which were previously used as complements or accessories (VALENTE, 2021), have come to play a major role in the form of teaching during social isolation.

Considering more specifically the subjects of Electronics, one possibility is the use of electronic circuit simulators, among which several free options can be found. However, as important or even more important than using a simulator or a technology is to define the teaching-learning methodology (OLIVEIRA et al., 2021), as proposed by Wang (2009), through a closed-loop system that includes steps for the student to get in touch with the content and be an actor in his own learning. The laboratory classes of two subjects were analyzed. The first, on Basic Electronics, in which the laboratories were carried out entirely in the form of ERT classes; and the second, Electronic Drives, whose laboratory classes took place in person.

Report on practical lessons using simulators in Basic Electronics

At the beginning of the second half of 2021, in August, there was still no exact forecast for returning to face-to-face classes, and all the content that was planned in the emergency remote form for the subjects had already been taught. In this way, it was necessary to return in person to carry out the laboratory classes and complete each subject. In August, so that the students would not have their course paralyzed, the missing classes of the Basic Electronics subject that would be in the laboratory were also adapted to the ERT format, allowing the conclusion of the same. Basic Electronics was chosen to be offered in this format because it was, among the subjects partially taught in ERT, the one that would have the most free-simulators available and appropriate to the content. It was planned to use the month of August exclusively for this subject, with what we will call “simulation classes”. Such methodology also had the objective of dealing with the challenge of keeping the students motivated, seeking methodologies that promote the students leading role in their own learning. This issue was already a concern even before social isolation, as we can see in the paper by Costa and Coutinho (2019), in which the authors cite the use of interactive online tools and active methodologies to promote student leading role.

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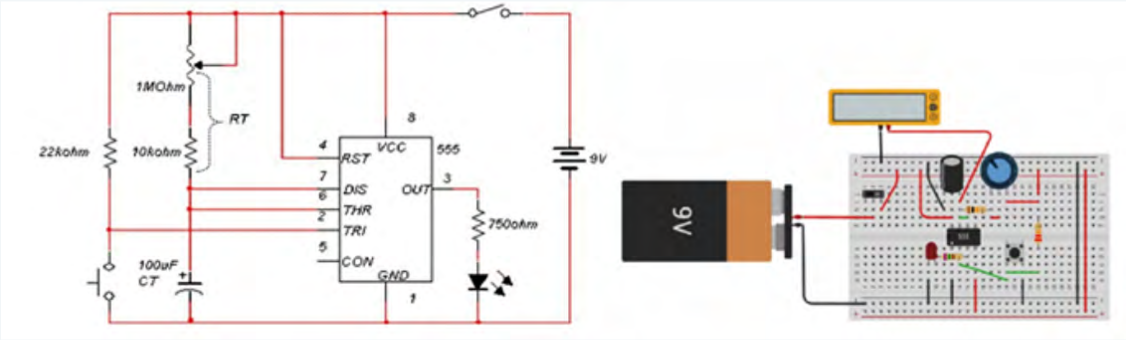
The simulation classes were offered more rigidly than the previous classes in ERT. Attendance at Google Meet was required, that is, just watching the recording and carrying out activities afterwards would not count as attendance. In this way, a more active participation of the students was sought than in the previous period in ERT, in which it was necessary to be more flexible so that there would not be even more dropouts. An effort was also made to prepare students for the face-to-face return, which was expected to take place soon, by demanding attendance and timetables.

After consulting the students regarding the availability of technological resources, it was found that all 12 enrolled had access to a computer at home (coincidence or not, the students who remained active in the course during the pandemic had access to a computer and internet at home). It was also observed that the operating system that the students had allowed the use of the planned software. TinkerCAD (AUTODESK, 2021a) was used to assemble and simulate electronic circuits and Eagle (AUTODESK, 2021b) to design circuit boards, both free and with materials and tutorials available on the web.

Starting with lessons in TinkerCAD, the teacher demonstrated the assembly of the day's circuit, deliberately leaving some gaps. In the first class, there were few gaps, demonstrating the assembly and the expected results almost step by step. Each student was able to share the link to their own simulation and it was possible to follow it in real time, helping them solve the problems thanks to this feature. In each following class, the day's circuit was explained with more gaps, so that students needed to research or create their own solutions. In the last class with TinkerCAD, the task was to assemble a timer circuit based on the classic IC 555, but without showing anything in the simulator. From the schematic and component data sheets, the students developed their own simulation on a virtual prototyping board. The Figure 1(a) shows the schematic made available to the students, while Figure 1(b) shows the assembly performed in TinkerCAD.

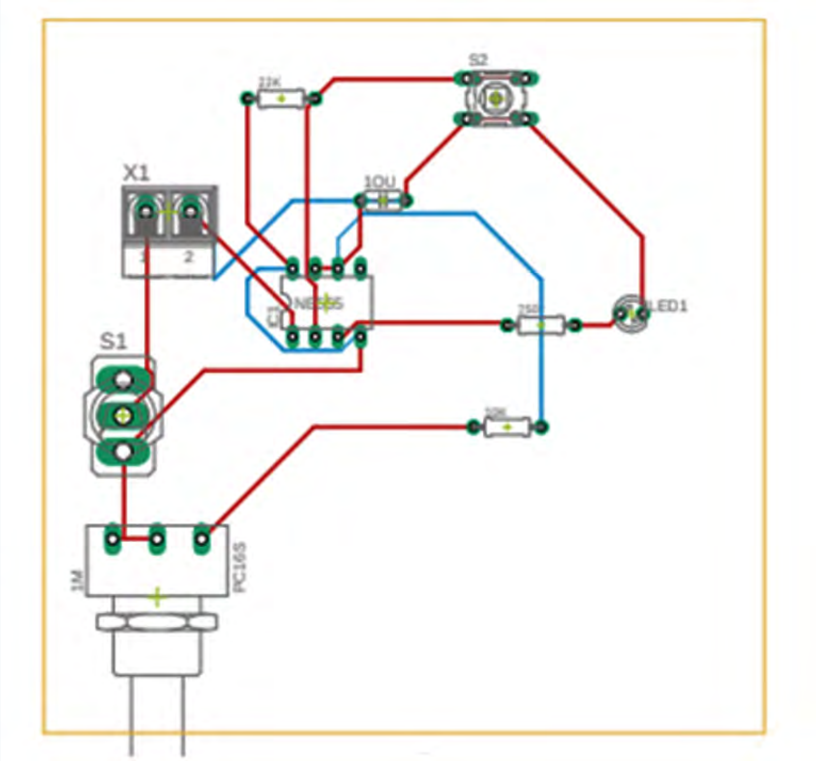
Figure 1 - Schematic made available to students (a); circuit assembled in the TinkerCAD simulator (b)



Source: (a) Pereira, 2014; (b) Authors: circuit assembled in TinkerCAD.

After the circuit was assembled, the Eagle software was used to design the timer's printed circuit board. A video tutorial was made available, showing how to install and design the board. Of the 12 students enrolled, seven completed the Basic Electronics subjects.

Figure 2 - Eagle software printed circuit board design submitted by a student



Source: Basic Electronics student.

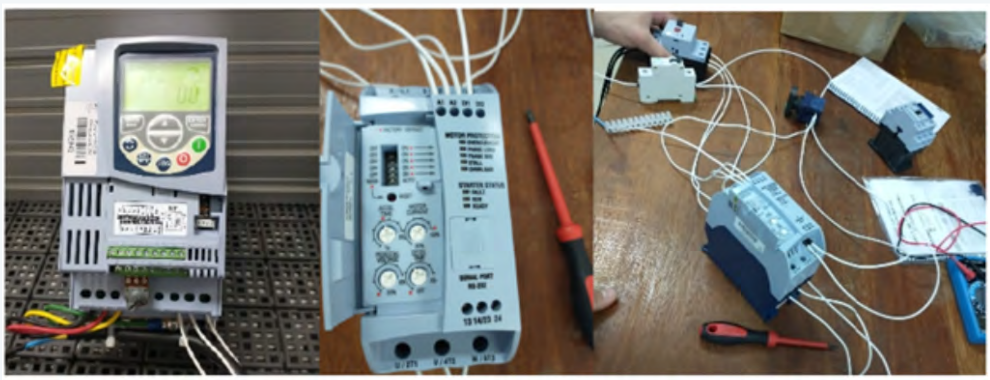
In short, the methodology used was to perform, in sequence, lectures lessons with exercises, the use of the TinkerCAD simulator to connect the components in a prototype circuit, and finally, the design of the board to manufacture a final circuit, going from the prototype to the product. With face-to-face classes, the main differences, besides the issue of engagement, would be the use of physical prototyping boards to assemble what was done in TinkerCAD, and after designing the board, it would be possible to print the design obtained for the circuit on a real board and visualize the result, including the imperfections that naturally occur during manufacturing. In this way, despite the limitations mentioned, it was possible to work theory and practice together, even remotely.

Report of face-to-face practical classes of Electronic Drives in the laboratory

At the beginning of September, shortly after the Basic Electronics simulation practices were completed, it was possible to carry out the face-to-face return for the Electromechanics course class, and one of the subjects whose face-to-face practices were offered was Electronic Drives. The practices planned for the laboratory were the assembly and programming of a frequency inverter and a soft starter.

The contents were resumed during the experiments, seeking to contextualize the information. For example, when the students energized the inverter through the alternating three-phase network, the question was raised: how can the inverter supply a direct voltage at one of its outputs if the energy input is alternating? At this point, the students related the concept of the rectifier circuit, present internally in the inverter, which performs this function, to the activity. In this way, all content seen in remote classes was reviewed and related to the physical equipment being operated by students, promoting the inseparability between theory and practice.

Figure 3 – Photos taken by students during practical classes



Source: Electronic Drives students.

Comparative

Two experiences of finishing subjects affected by the pandemic were reported. In both, classes were held through ERT, filling all the contents foreseen, but with outstanding laboratory activities. In Basic Electronics, these practices were performed remotely by means of simulators, and in Electronic Drives the laboratory activities occurred in a face-to-face manner.

As a criterion for comparison, the teacher's perception of the students' engagement with the two subjects is reported. The teaching strategies used in both subjects mentioned sought to maintain, as far as possible, students' contact with practice, since face-to-face classes represent an important vector for the effective completion of subjects. In Basic Electronics, there was a significant increase in motivation with the course compared to previous emergency remote classes, as they knew they could finally complete the subject and realized that face-to-face classes could soon be resumed. However, it was also clearly perceived that the students were making an effort only because they knew they could complete the subject and approach the end of the course. There was a greater involvement in the first classes, but it was reduced, so that in the last classes it was necessary to contact the students several

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times to demand the completion of the activities. The students only spoke up during class to question details of the implementation, errors that were happening, but they did not question why or anything deeper. In Electronic Drives, in the very first face-to-face class, we observed students talking more, even in a relaxed way, something that was practically non-existent during the ERT classes. In addition, participation and attendance were continuous from the first to the last class.

In order to analyze the students' engagement, the quantity and depth of questions asked by the students in class were also compared. In Basic Electronics, the questions came in a more superficial way, asking only what they should do to make a certain circuit work correctly, but without asking why. It was also observed that other problems, such as a student to assemble a circuit that had not worked correctly and simply stated that the circuit did not work, were reported directly in the form of negative statements, with no demonstration of proactivity. It was verified that, with the use of the simulator, the students performed the activities with greater assiduity in relation to the theoretical contents, which demonstrates the need to unite theory and practice, but still without the same engagement observed in face-to-face classes of the same course.

In Electronic Drives, on the other hand, the students asked more questions with a greater level of depth, reporting the doubt and arguing about the causes of the observed problems and the possible solutions. This complement, of argumentation, of an attempt to find an explanation, made the dynamics of the practical classes much more productive. Additional comments were also noted citing the differences and similarities of the practices in the laboratory and those performed in the companies where they work. Such comments, answered by the teacher, led to further discussions, so that the classes always reached some goals beyond what had been planned. This effect can be explained by the course audience, which is mostly made up of workers with professional experience.

Finally, student performance was analyzed as an indicator of engagement. In both subjects, classes were held via emergency remote classes. In such previous classes, in Basic Electronics, some simulators had already been used, but as a return was expected soon, activities of a more theoretical nature were performed. In Electronic Drives, there were no suitable free simulators, classes in ERE format were limited to theory. But what was observed is that, in both subjects, students arrived at the laboratory (physical or virtual) with prior knowledge, which facilitated the development of activities. Here we highlight the need for the laboratory learning stage, whether physical or virtual, in which students can experiment and visualize, with their own conclusions, the phenomena studied during the lectures, to ensure the inseparability between theory and practice. For example, in Basic Electronics, when a circuit with diodes was assembled, all the students assembled the component on the board in the correct direction (current in the anode-cathode direction), closed

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the circuit in the negative pole of the source (they did not leave an open circuit), did not cause short circuits, among other things. In other words, although in the ERT format, in which even with the use of simulators, when available, the classes had limitations in terms of practice, there was significant learning. In face-to-face classes on Electronic Drives, the same effect was observed, with the students respecting the basic concepts. The students already understood, for example, what the acceleration and deceleration ramp was, that the inverter supplied voltage at variable amplitudes and frequencies and did not cause any short circuits or accidents during the classes. Therefore, the hybrid format, combining simulations and video classes prior to laboratory classes, contributed to the progress of the course.

Conclusions and lessons for the future

The first conclusion is that the "solution" used to keep the course running did not solve the problem caused by the need for social isolation in its entirety, because most of the practical activities in physical laboratories necessary for the completion of the course could not be replaced by virtual activities with simulators. As examples, can be quoted the Electronic Drives practices reported here, and welding and machining practices present in other subjects of the course. The decision to keep the course in ERT format was the result of a compromise between enabling students' training and not hindering their learning through classes that are not fully appropriate for the course. In other words, the aim was to minimize the harm to students. Simply approving students for a course that requires laboratory classes only with remote emergency classes would not be a viable alternative, as we would not be meeting the minimum required of an electromechanical professional. In the same way, paralyzing the course completely, waiting for the face-to-face return, would be a huge harm to the students who had already committed time, effort and planning in the initial semesters of the course.

The second conclusion, and also a learning one, is that the Electromechanics course, considering normal times, can benefit from strategies developed during the remote emergency classes, such as the more frequent use of simulators, video lessons available on the web and online review quizzes, as a complement to face-to-face teaching, since such strategies optimize time in the classroom. The proper use of simulators has enabled contact with practice that, although not a full substitute for classes in physical laboratories, may be used together with classroom activities. It is also observed that, regardless of whether there is a pandemic or not, it is imperative that in the first semester of the course, training is given in the use of digital technologies, such as email, the institution's academic system, search tools, among others.

Another important learning was that the students of the course, when unhappy, hardly manifested about it, even if questioned directly. The tendency among students who dropped out was to give some explanation such as "I changed jobs, I had some difficulties, etc.”. Only one student explicitly stated that he did not participate in the ERT classes because he did not adapt to the format.

Analyzing the performance of the activities in this experience report, we verified that in Basic Electronics, taught entirely remotely, it was possible to work the minimum content foreseen for the subject with the use of software, but with a lower effectiveness than expected in normal times with face-to-face classes. However, the positive aspect of the remote classes stands out, with a dynamic of intensive use of simulators in Basic Electronics, as a preparation for the face-to-face return, even if this only occurred in the subject of Electronic Drives. In the return to the classroom, in Electronic Drives, the dynamics of the classes was also intensively practical, applying the concepts worked on during the remote emergency classes. It was clearly observed that face-to-face classes provided greater student engagement.

As future work in this line of research, we propose a greater exploration of digital technologies as a complement to classroom lessons, the systematization of materials and online questionnaires, and a closer analysis of the students reality to better understand the difficulties that they find.

References

AUTODESK. **Eagle**. 2021a. Disponível em: https://www.autodesk.com/products/eagle/free-download. Acesso em 9 nov. 2021.

AUTODESK. **TinkerCAD**. 2021b. Disponível em: https://www.tinkercad.com. Acesso em 5 nov. 2021.

BOND, Melissa; BEDENLIER, Svenja; MARÍN, Victoria I.; HÄNDEL, Marion. Emergency remote teaching in higher education: mapping the frst global online semester. **International Journal of Educational Technology in Higher Education**, [s. l.], v. 18, n. 50, p. 1-24, 2021. Disponível em: https://link.springer.com/content/pdf/10.1186/s41239-021-00282-x.pdf. Acesso em: 25 ago. 2022.

COSTA, Maria Adélia; COUTINHO, Eduardo Henrique Lacerda. Metodologias ativas e currículo integrado: a travessia para as práticas pedagógicas motivadoras na educação profissional técnica de nível médio. **Boletim Técnico do Senac**, Rio de Janeiro, v. 45, n. 7, p. 7-20, set./dez. 2019. Disponível em: https://www.bts.senac.br/bts/article/view/792. Acesso em: 25 ago. 2022.

COUTINHO, Carlos Roberto. Utilização de programas de simulação de circuitos no ensino de eletricidade e eletrônica. *In*: CONGRESSO BRASILEIRO DE EDUCAÇÃO EM ENGENHARIA, 41., 2013, Gramado. **Anais** [...]. [*S. l.*]: ABENGE, 2013.

HART, Daniel W. Circuit simulation as an aid in teaching the principles of power electronics. **IEEE Transactions on Education**, [*s. l.*], v. 36, n. 1, p. 10-16, fev. 1993. Disponível em: https://ieeexplore.ieee.org/abstract/document/204808. Acesso em: 25 ago. 2022.

OLIVEIRA, Muriel Batista de *et al*. O ensino híbrido no Brasil após pandemia do covid-19. **Brazillian Journal of Development**, Curitiba, v. 7, n. 1, p. 918-932, jan. 2021. Disponível em: https://www.brazilianjournals.com/index.php/BRJD/article/view/22597. Acesso em: 25 ago. 2022.

PEREIRA, Nuno. O 555 como temporizador (monoestável) regulável. **[Blog] Electric Ideas**, [*s. l.*], 2014. Disponível em: https://electricideas.wordpress.com/2014/03/29/o-555-como-temporizador-monoestavel-regulavel/. Acesso em: 5 nov. 2021.

SILVA, Carlos Alexandre Gouvea da; SANTOS, Edson Leonardo dos; PELACINI, Douglas Antonio Firmino. Evaluation of academic experience in learning education over simulator softwares. **International Journal of Alive Engineering Education**, Goiânia, v. 2, n. 5, p. 23-40, jul./dez. 2018. Disponível em: https://www.revistas.ufg.br/ijaeedu/article/download/54716/26998. Acesso em: 25 ago. 2022.

SUMMIT, Raymond.; RICKARDS, Tony. A construtivist approach to mathematics laboratory classes. In: DELTA CONFERENCE ON TEACHING AND LEARNING OF UNDERGRADUATE MATHEMATICS AND STATISTICS, 9., 2013, Kiama, Australia. **Anais** [...]. [*S. l.* : s. n.], 2013.

VALENTE, Geilsa Soraia Cavalcanti; MORAES, Érica Brandão de; SANCHEZ, Maritza Consuelo Ortiz; SOUZA, Deise Ferreira de. O ensino remoto frente às exigências do contexto de pandemia: Reflexões sobre a prática docente. **Research, Society and Development**, [s. l.], v. 9, n. 9, p. 1-13, 2020. Disponível em: https://rsdjournal.org/index.php/rsd/article/view/8153/7109. Acesso em: 25 ago. 2022.

VALENTE, Solan Arantes. Transição do modelo de ensino presencial para o remoto no contexto do isolamento social: a experiência do TECPUC. **Boletim Técnico do Senac**, Rio de Janeiro, v. 47, n. 2, p. 98-113, maio/ago. 2021. Disponível em: https://www.bts.senac.br/bts/issue/view/92/144. Acesso em: 25 ago. 2022.

WANG, Guoping. Active learning in digital electronics: preview, exercise, teaching and learning. In: INTERNATIONAL MULTI-CONFERENCE ON ENGINEERING AND TECHNOLOGICAL INNOVATION, 2., 2009, Orlando. **Proceedings** [...]. [*S. l.* : s. n.], 2009. Disponível em: https://www.iiis.org/cds2008/cd2009sci/imeti2009/paperspdf/f665aa.pdf. Acesso em: 25 ago. 2022.