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The Impact of "Going Virtual" on Engineering Education During the COVID-19 Pandemic: A Student-Centered Study in Colombia*

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Several studies have been able to explore students' reactions to how the COVID-19 pandemic has affected learning processes. However, most of that research is specific to medical education and, while there exist some contributions in the context of engineering education, student-centered studies seem to be very limited. This study examined the perception of being forced to move to online learning in a population of electronic engineering students attending the Electronic Circuits I (EC-1) course offered by Universidad Santiago de Cali, a private university in Colombia. Data was collected through a 6-item survey comprised of questions to be responded to on a 6-point Likert-type scale and a written essay. Most of the respondents provided positive feedback on the guidelines and preparation provided by the instructor for the transition to online learning. However, some students perceive that online learning is not sufficient to bridge the gap between theory and practice. Moreover, Internet service access and an adequate learning environment at home are essential for effective online learning. Based on the experience lived during the transition, some recommendations are also provided.

Keywords: Engineering education; COVID-19; e-learning, students' viewpoint; electronic circuit courses

1. Introduction

The term "distance education" often refers to an alternative teaching and learning model based on the use of digital contents and tools to provide online interaction and collaboration between students and their instructors, outside of a traditional classroom [1]. In the Colombian context, the National Accreditation Council mentions that distance education is a methodological strategy to increase access opportunities to higher education and, therefore, to facilitate the entry of a greater number of students to the educational system [2]. In this country, distance education has shown considerable growth mostly due to the increase in connectivity and the decrease in Internet service costs, so several institutions have adopted this model in some of their programs and/or courses [3]. This process has occurred as a result of several years of planning, in an attempt to address the socio-economic needs of each region. Nevertheless, this has not been the case for many other institutions in Colombia which, in response to the coronavirus (COVID-19) outbreak, have been forced to rapidly adapt to online classes in order to guarantee continuity of teaching and learning processes.

As the COVID-19 pandemic continues to develop, the literature body regarding its implications for education is increasing day by day. To date, a search on Google Scholar using "COVID-19" and "education" as keywords yields 934,000 results, even though not all of them are equally relevant because Google Scholar casts a broader net. Most of these results include the term "medical" or a medical-related term in their titles, thereby suggesting that the impact of COVID-19 on medical education is receiving well-deserved attention [4–6]. In this context, a considerable body of work has been able to assess students' reactions to how the pandemic has affected learning processes [7, 8]. There are also some studies on the effects of the pandemic on science [9–11] and engineering education [12–15]. However, in the context of engineering education, student-centered studies seem to be much less common [16]. This study aims to examine the perception of being forced to shift from the traditional face-to-face classroom methodology to digital learning in a population of electronic engineering students of the Pampalinda campus of Universidad Santiago de Cali (Santiago de Cali, Colombia). The present work is expected to encourage further endeavors to perform a more extensive analysis of how electronic engineering students have been affected by the suspension of face-to-face classes. Some strategies to tackle the identified issues are also proposed.

2. Background

Electronic Engineering programs are of great importance worldwide, since this discipline has

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extended to multiple fields and has enabled the advancement of technology and society. Based on this, several Colombian universities have undergone a process of curricular transformation of their Electronic Engineering programs [17], always aiming to bridge the gap that still exists between what is taught in college and what is demanded by companies and organizations [18]. In line with such efforts, some research has been conducted to identify the learning strategies used by electronic engineering students [19], as well as to assess the impact of their utilization on the students' academic performance. All this has been carried out with the purpose of adjusting to the needs of each region, which in turn are constantly changing.

The Electronic Circuits I (EC-1) course has been delivered over a 15-years period to 5th-semester students of the Electronic Engineering Program at the Pampalinda campus of Universidad Santiago de Cali. The course was designed to provide learners with a solid foundation in the concepts of analog circuits' analysis and design. Topics covered include semiconductor physics and devices, diodes, bipolar junction transistors (BJTs), small signal and large signal analysis, operational amplifiers, and analog circuits and applications. Laboratory sessions are also significant components of the course. Students always enter with little or no experience in analog circuit design. The EC-1 course is delivered for 16 weeks by 3 contact hours of lectures per week (total of 48 contact hours), and it is assessed via two quizzes, one final exam, and two-three laboratory exercises. Students are required to attend laboratory sessions using a detailed laboratory manual, which is delivered by the professor one week in advance. They are also grouped in pairs for the laboratory sessions, and they also have to buy electronic components for every project.

3. Methods

The instrument used for data collection consisted of two parts (see Table 1). The first part was a 6-item survey comprised of questions to be responded to on a 6-point Likert-type scale (totally agree, strongly agree, slightly agree, slightly disagree, strongly disagree, and totally disagree). Although 4-point scales are desirable for young respondents because they are easy to understand and they require less effort to answer, 6-point scales provide the possibility of increased measurement precision [20]. The second part was an essay on how electronic engineering students perceived the current urgent shift to online learning because of the COVID-19 pandemic. The survey was initially conducted in Spanish, which is the official language in Colombia, and the Google Forms tool was employed to create the questionnaire for its distribution via email. Before the survey was sent to the students, it was previously reviewed by five instructors and researchers (three from the Faculty of Education and two from the Faculty of Engineering) to receive feedback on the wording and quality of the items. All experts made suggestions that were considered and included in the questionnaire, such as being more specific about the conditions that might be essential for students' effective learning at home (see item #4 in Table 1).

The questionnaire was sent via email on July 20 of 2020 to all the students of the Pampalinda campus of Universidad Santiago de Cali attending the Electronic Circuits 1 course during the period between February–June 2020. None of the messages sent was returned as undeliverable, thereby leaving a total of 28 potential respondents.

4. Results

A total of 26 questionnaires were returned (response rate of 92.85%). Regarding the first part, about 73.08% of the students were aged 19–23 years and 26.92% were aged 24–28 years. Furthermore, 24 participants were male while only 2 were female. Fig. 1(a–f) summarizes the distribution of answers for the six questions. The majority of the respondents agreed on all state-

Table 1. The instrument used in this study

Part 1	
Item	**Statement**
#1	I had good Internet access to connect to the online class from my Laptop or Smartphone
#2	The instructor gave us orientation on the use of e-learning platforms prior to the college closure
#3	Online sessions were highly effective for learning all the topics of the course
#4	I had adequate conditions (like quite and comfort) at home to contribute to my learning
#5	It was possible to attain a balance between theory and practice through online classes
#6	The instructor showed good performance when using e-learning platforms to cover the topics of the course
Part 2	
How did I perceive the urgent shift to online learning because of the COVID-19 pandemic? Please highlight the opportunities and challenges posed by this particular circumstance.	

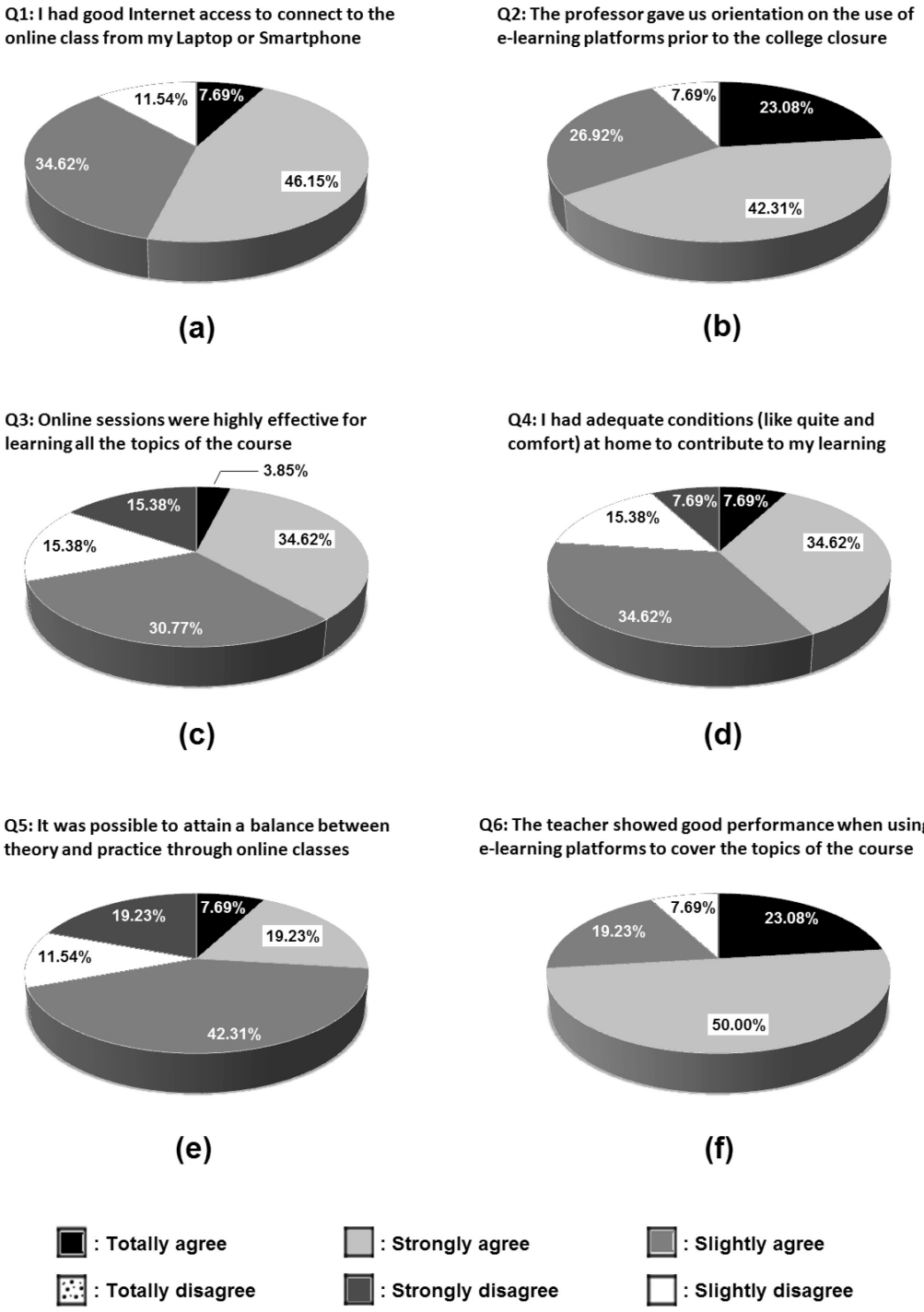

Fig. 1. Feedback on online classes provided by students attending the Electronic Circuits 1 at Universidad Santiago de Cali.

ments, although the level of agreement varied between statements. The highest level of agreement was achieved on items #2 ("The professor gave us orientation on the use of e-learning platforms prior to the college closure") and #6 ("The teacher showed good performance when using e-learning platforms to cover the topics of the course"). On the other hand, the lowest level of agreement was achieved on items #3 ("Online sessions were highly effective for learning all the topics of the course") and #5 ("It was possible to attain a balance between theory and practice through online classes").

Students' written essays were also collected, which added up to 31 text pages for analysis. As done by Naji and colleagues [16], a thematic analysis was conducted to explore the comments and opinions of the participants, who mostly agreed

that it was better to shift to online learning than to postpone the semester. On the other hand, more than one-third of the respondents expressed their concern about the limitations of online learning during laboratory exercises. As one student wrote:

> "One hopes to enter the laboratory and acquire the necessary skills to handle the instruments that we will use for the rest of our careers. Simulations are very useful as a prelude or complement to laboratory experience, but not as a substitute."

Despite this and other similar statements, most of the respondents (more than 65%) gave positive feedback on the use of simulation environments (e.g., tinkercad) to complete laboratory exercises. Moreover, since students did not have to buy the electronic components required for every project, the utilization of simulation tools during laboratory sessions was considered as an advantage over the traditional face-to-face laboratory methodology. As written by one student:

> "The use of simulation tools provided some financial relief since, in general, I find it very difficult to buy some of the electronic components required to complete the laboratory projects."

Another example was:

> "There are no electronic stores selling the components required to perform the laboratory exercises. In that sense, the use of simulation environments allowed me to complete lab activities and maintain my performance throughout the course."

The majority of the participants (more than 85%) also provided positive feedback on the orientation and preparation for the transition to online learning. As one student wrote:

> "Clear guidelines and instructions were provided by our instructor several days before the online learning was adopted. I think that really helped me to reduce the stress and insecurity that many (if not all) of us experienced during the transition."

EC-1 students provided different opinions regarding online teamwork. For instance, one student wrote:

> "My group and I were able to achieve online teamwork by using the Whatsapp group chat. In fact, the lockdown did not affect our teamwork negatively because we were used to online teamwork even before the University closure."

On the other hand, another student wrote:

> "Sometimes it was difficult for me to coordinate certain types of activities with my teammates since the communication was not as fluid as that when you are face to face with the other person."

Last but not least, more than two-thirds of the respondents expressed their desire to return to the classroom in the short- or medium-term. As one student wrote:

> "I really appreciate the shift to online learning as a response that prevented the course, and the semester, from being postponed. Nevertheless, I also expect to return to the classrooms as soon as possible, because I cannot see myself attending an online course which is supposed to be delivered face-to-face. I think my classmates and I could miss something important."

5. Discussion

From Fig. 1a, 88.46% of the respondents agreed on having good Internet access to connect to the online class, either from a Laptop or Smartphone, whereas 11.54% of the respondents disagreed with that statement. From the written essays, it was possible to observe that some students have no computer for their personal use, or that they live in rural areas where Internet access is somewhat limited. As in many other developing countries, limited Internet access may be attributable to economic (high costs) and technical (signal availability/strength) reasons [21]. This lack of access has been acknowledged as an important limitation of online learning [22] and it may influence negatively the students' perception towards the adoption of online learning methodologies. In one similar study conducted in Ghana [23], 73.8% of the students disagreed that the online system of learning is very effective, mainly due to the lack of access to the Internet service on the part of many Ghanaian students (more than 60% of the respondents reported having no Internet access in their locality to attend online classes). Having a portable device with Internet access is, therefore, essential for attending online classes. However, it takes much more than that for students to be able to learn effectively from home. It is necessary, for instance, to create a calm and comfortable environment so that students can concentrate on learning. In this regard, although 76.92% of the respondents agreed on having adequate conditions at home to contribute to learning, 23.08% disagreed with that statement (Fig. 1d). A possible explanation is that many homes in developing countries do not provide an adequate learning environment, thereby forcing students to learn either in the living room or their bedrooms [23]. Furthermore, students may be exposed to many distractions (e.g., T.V., siblings' homeschooling, and even the Internet itself [16, 22]), which may hinder learning and understanding. In this sense, success in the adoption and use of digital learning would depend not only on the effective integration of e-learning technologies and pedagogies, but also on ensuring that all students have adequate resources and conditions that allow them to effectively learn at home.

Fig. 1c shows that 69.23% of the respondents agreed that the virtual environment was highly effective for learning all the topics of the course. Nevertheless, 30.67% of the respondents disagreed with that statement. Interestingly, item #5 ("It was possible to attain a balance between theory and practice through online classes") achieved a similar agreement/disagreement ratio. Additionally, more than one-third of the respondents used their essays to express their concern about the shortcomings of online learning during laboratory exercises. These results may differ from those reported by similar studies, in which the level of agreement on the use of virtual environments to perform laboratory experiments was much higher [14–24]. Nevertheless, the fact that a considerable proportion of engineering students perceive that online learning may not be sufficient to bridge the gap between theory and practice should not be overlooked. While the aforementioned studies have reported high rates of surveyed students expressing their liking for the use of virtual tools to complete laboratory exercises, they have also pointed out some limitations in the use of virtual environments for the learning processes that take place in laboratory sessions. Such barriers include the absence of genuinely experimental content and the lack of interaction [14]. The level of interaction achieved through laboratory activities in engineering education has proven to contribute to increasing student understanding and maintaining student engagement [25, 26]. In the context of electronic engineering, students not only build and test circuits during laboratory exercises but also develop the skills to properly use traditional measurement instruments such as multimeters and oscilloscopes. It also forces students to be cautious when connecting electronic components, which may not occur in digital learning as a result of the sense of security provided by circuit simulation environments. Thus, first-hand experiences and effective skills development provided by traditional laboratory sessions might not be fully acquired through the emergency shift to online learning.

The high level of agreement achieved by items #2 and #6, as well as the positive feedback on the guidelines and preparation provided by the instructor for the transition to online learning, are consistent with results yielded by one recent study conducted in Qatar [16]. On this particular aspect, and in the context of our institution, two factors possibly made the difference, (1) having programs and/or courses that have already adopted the distance education model, and (2) receiving constant training on the use of e-learning platforms (e.g., Moodle, Google Classroom). As the number of infected people in Colombia increased, educators were requested to expeditiously adapt their learning support material by moving as much online as possible. Students were also guided to make sure that they register and get connected to the e-learning platforms to avoid missing out sessions. Instructors from virtual programs shared their experience with us a few days before institution closure. Thus, it was possible to provide students with orientation on the use of e-learning platforms so that they can continue to learn. Hence the importance of updating academic staff on the demands of emerging e-learning technologies, as well as how they are used [27]. As suggested in [23], training on such technologies must be provided to educators at least once a year.

Through the written essay, it was possible to identify some topics that were not explicitly mentioned in the first part of the questionnaire. One of those aspects was related to the appropriateness of the institution's decision to migrate to online learning, which provided students with an opportunity to continue their studies. This aspect has been examined by other authors [16] and it might depend on how clear it is for students the way in which the change is introduced and the strategies supporting that change. This highlights the importance, not only of providing students with detailed and accurate information about the use of online platforms, but also of verifying whether this information has totally been understood. The other aspect is related to the students' expectations of returning to the classroom in the short- or medium-term, which was expressed by more than two-thirds of the respondents (n = 19) in their written essays. This might be motivated by several factors, including a potential need for interaction with instructors and classmates. Students might feel isolated due to the "impersonal" character of the online learning process [22], so further efforts are currently needed to develop novel teaching strategies highlighting interactive and collaborative learning in courses delivered online.

Despite the aforementioned findings, the present work also has its limitations. First, the study was focused on one specific course and, therefore, only a limited number of participants were surveyed. The number of students attending the EC-1 course offered by Universidad Santiago de Cali usually ranges from 15 to 35, which is in fact a very small number when compared with that of similar studies [16, 23]. The motivation behind choosing the EC-1 course is that it is an introductory course and, as such, it is crucial for the training of electronic engineers and it has a strong practical component, mainly represented by laboratory sessions. Unlike other courses that are mainly focused on lectures, the EC-1 course demands high levels of interaction

and teamwork, which could be affected as a result of the emergency shift to online learning, motivated by the COVID-19 pandemic. This and several other issues should be examined from the stakeholders' perspective, and especially from that provided by the students, whose voices need to be heard to overcome the barriers and maximize the benefits of moving to online learning [28]. Another limitation of this work is that data analysis is purely descriptive, and no statistical tests were applied. However, qualitative data is also relevant to provide insight and better understand the phenomenon under study [29], and several studies that are also relevant in the context of the current educational disruption were conducted on a similar basis [8, 12, 21, 23]. Still, further research is needed to examine the challenges faced by engineering students during the urgent shift to online learning.

At this time, every course offered by Universidad Santiago de Cali is mainly delivered online, and it is expected to continue that way in 2021. Based on the experience lived during the transition, some recommendations are pointed out below:

- Faculties should provide continuous training on the use and adoption of e-learning platforms, at least once a year [23]. Thus, instructors can be better prepared to deliver courses online in the event of an emergency like the current one.
- Faculties and instructors should include activities that can be developed by using open source and very affordable software and hardware resources. For instance, electronic circuit simulations can be performed on platforms like tinkercad, which is a free, easy-to-use, online modeling program. Likewise, many projects can benefit from using programmable circuit boards like Arduino boards which include two voltage-sources (+3.3 and +5 Volts), a 10-bit analog-to-digital converter, and provide the ability to visualize up to 6–10 different signals through the Serial Monitor tool.
- Local and regional governments should support educational institutions in providing students with computers or Laptops to attend online classes, perhaps through educational credits. While Smartphones represent an opportunity to access the Internet, they also may limit the skills needed to achieve a more complete digital inclusion [30], which is essential to online learning. Moreover, a considerable amount of online content is not accessible via Smartphones [21]. Further efforts are also needed to increase broadband Internet access in rural or remote areas, as well as to improve the partnership between institutions, which may reduce costs and risks.

6. Conclusion

The COVID-19 outbreak, and the resulting closure of educational institutions' have imposed a paradigm shift in terms of the learning and teaching processes. Most of the colleges and universities have quickly adapted to online classes to continuously provide education. However, this measure could be insufficient for courses requiring the use of a laboratory where students have the opportunity of having first-hand experiences, which are necessary and significant for learning in engineering programs and/or courses.

To analyze the impact of "going virtual" on learning processes, students' feedback needs to be considered. Due to the limited size of the sample, this study only scratches the surface of a field where the information available is limited, and more research is needed to reevaluate pedagogical approaches in several engineering areas to maintain a proper balance between theory and practice when e-learning technologies are adopted.

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