# Virtual Learning Approach to Biological Engineering Courses in Uruguay During COVID-19

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# ABSTRACT

### Design/methodology/approach

Global education has seen a significant paradigm shift over the last few years, changing from a specialized approach to a broader transdisciplinary approach. Especially in life sciences, different fields of specializations have started to share a common space in the area of applied research and development. Based on this transdisciplinary approach, the Biological Engineering program was designed at the University of the Republic *(Universidad de la República)*, Uruguay.

### Purpose

In times when digitized and blended learning paradigms are getting more profuse, the COVID-19 pandemic substantially changed the dynamics of this program, forcing all the courses to migrate to virtual modality. This study highlights the biological engineering courses at the University of the Republic *(Universidad de la República)* in Uruguay pertaining to the adaptations to virtual learning environments during the COVID-19 pandemic and analyzing its impact through the courses taught in the virtual setting.

### Findings

The new challenges posed by the virtual modality on the pedagogical areas like course design, teaching methodologies and evaluations and logistical aspects like laboratory-setting have sparked a considerable change in different aspects of the courses. However, despite the changes to virtual modality in this year, the student-performance showed an overall improvement compared to the last year.

### Originality/value

With the changing direction of pedagogy and research in biological engineering across the world, it is quintessential to adapt university courses to the same, promoting an environment where the scientific and engineering disciplines merge and the learning methodologies lead to a dynamic and adaptive ubiquitous learning environment.


**Keywords:** Education, Creativity, Innovation, Biological engineering, Peer-learning, COVID-19, Pandemic, Virtual Learning

## 1. INTRODUCTION

The status of education has always been one of the primary factors of development in defining academic capital, human resource and vision of development [1,2]. In the digital era, one of the crucial areas which needs to embrace newer technologies and cutting-edge paradigms is education. The Department of Biological Engineering of University of the Republic *(Universidad de la República)* Uruguay offers an undergraduate program on biological engineering based on the cross-fertilization between creativity and interoperability in a transdisciplinary environment [7], fusing the domains of engineering and life sciences. It aims at an enhanced learning experience for the students, providing them with state-of-the-art transferable skills to enable them to excel in a career in life sciences [5]. With the advent of the COVID-19 pandemic, due to measures taken by the national authorities, the university had to change the format of all its courses (Table 1) taught from March through December 2020 in the Department of Biological Engineering and adopted virtual learning through the first and second semesters of the year.

The courses of the Biological Engineering program share a common approach of merging the disciplines of health sciences, biology, and engineering, based on a transdisciplinary foundation. The objective is focused to the students obtaining transferable skills necessary for real-world problem solving. The program outcome includes possessing capabilities for working in multidisciplinary environments like the agri-food sector, biotechnology and bioinstrumentation sector, and even providing technological solutions to the healthcare sector. During the four-year undergraduate program of Biological Engineering (Figure 1), courses on engineering fundamentals and basic sciences are put mostly in the first two years, while the following two years are focused to the core concepts of life sciences and other specialized topics like informatics. Each year of the program contains a Biological Engineering workshop, which acts like an integrating thread guiding the students through the applied domains of the subjects and trains them in solving problems and studying biological systems through integration of disciplines of various kinds. The first- and third-year versions are focused on a broader transdisciplinary approach while the second- and fourth-year workshops are more specific to biological engineering.

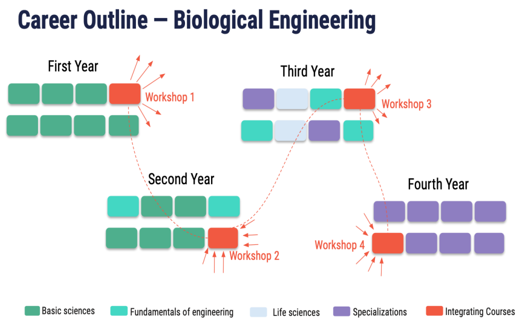



**Figure 1.** Outline of the undergraduate degree program of Biological Engineering in the University of the Republic *(Universidad de la República)*, Uruguay [9]

Adaptation to virtual learning for all the courses involved a series of pedagogical changes, including course design and teaching methods, which had a diverse impact on the students and the professors [9]. This study sheds light on the new changes adopted under the framework of virtual learning and analyzes its impact and dynamics.

## 2. COURSE DESIGN ADAPTED TO VIRTUAL LEARNING

A key objective of the Biological Engineering program has been to bridge the gap between the academic domain and problem-solving visions in real-world scenarios of biology. In this approach, the primary focus was on the course contents, teaching and learning paradigms and its relevance to the state-of-the-art. Also, the intention was to lead the students in independent thinking and problem solving while obtaining the necessary skills through the courses. With the compulsory shutdown of in-person activities at the university, all the courses of 2020 had to be shifted to virtual format, including 9 courses of the first semester and 6 courses of the second semester of 2020 (Table 1).

Table 1. Biological Engineering Specific Courses taught in virtual modality due to COVID-19

| Course | Year/Semester of the Biological Engineering program | Description |
|---|---|---|
| | | |
| Biological Engineering Workshop 1<br>*(Taller de Ingeniería Biológica 1)* | 1st year<br>(*first semester*) | This is the first course of the undergraduate program of Biological Engineering and gives a prima-facie impression of the entire program. It comprises of fundamental theoretical concepts of muscular physiology, cardiovascular systems, respiratory systems, neurophysiology, and a final module of applied projects. This course is highly critical because of its introductory pattern and has the highest number of students compared to any other course of the entire Biological Engineering program. |
| Programming 1<br>*(Programación 1)* | 1st year<br>(second *semester*) | This course seeks for students to acquire practical and theoretical knowledge about algorithms and fundamental data structures in an imperative programming language. It deals with aspects of problem formulation using a programming perspective and the analysis of several programming solutions to reach optimal solutions. |
| Circuit Theory<br>*(Teoría de Circuitos)* | 2nd year<br>(*third semester*) | This course provides a preliminary view to linear circuits, familiarizing the students with basic tools for analysis and synthesis of circuits. Students learn to solve circuits based on linear operational amplifiers, to understand the main theorems of circuit analysis, are introduced to Bode diagrams, and filters, practicing the handling of electronic laboratory instruments. Also they are introduced in the specific technical nomenclature in electrical engineering, among other concepts, all linked to applied areas of biological engineering. |
| Programming 2<br>*(Programación 2)* | 2nd year<br>(*third semester*) | The objective of this course is to provide fundamental methodologies for the design of small and medium-sized programs, using techniques for the formulation and implementation of data abstractions. The aim is for students to acquire programming experience in a specific language that allows them to exercise modularization techniques and applying best programming practices. In this course, students exercise data composition techniques and recurrence programs, and gain experience in the use of pointers and dynamic structures, classic algorithms of traversals and sorting, and basic concepts of time and space complexity. |

| | | |
|---|---|---|
| Biological Engineering Workshop 2<br>*(Taller de Ingeniería Biológica 2)* | 2nd year<br>(*fourth semester*) | This course focuses on training the students with the knowledge of basic sciences, in order to develop the capacity for reasoning and analysis of systems with biological orientation through the principles of engineering. An attempt is made to achieve a philosophy of scientific reasoning that will be applicable to the rest of the career and the trained professional. This course seeks to develop the ability to study and understand a model of a biological system through familiarization with physical and mathematical modeling tools and simulation, familiarizing the student with processes of scientific experimentation and experimental validation of results, and developing the ability to integrate knowledge from different disciplines through practical projects and hands-on approaches. |
| Signals and Systems<br>*(Señales y Sistemas)* | 3rd year<br>(*fifth semester*) | This course imparts the knowledge of the mathematical modeling of signals and systems. It is intended that the students understand the complexity of mathematical modeling and become familiar with the mathematical tools that allow simplifying this process through spectral analysis for both discrete and continuous systems. |
| Electronics 1<br>*(Electrónica 1)* | 3rd year<br>(*fifth semester*) | This course aims at providing the students necessary capabilities to understand and handle electronic circuit design and analysis methodologies. Also, it imparts the knowledge of the physical principles on which the operation of semiconductor devices is based and how they provide the required functionality, the principles determining the main characteristics of electronic devices. In addition, this course provides necessary skills needed to deal with the information provided by the manufacturers of electronic components. |
| Biological Engineering Workshop 3<br>*(Taller de Ingeniería Biológica 3)* | 3rd year<br>(*fifth semester*) | This course seeks to provide an overview of the different applied fields of biological engineering. The objectives are focused on the formation of students with knowledge of basic sciences, developing their ability to integrate the acquired knowledge and apply it to concrete problems of reality. This subject is of vital importance for the discipline in the Biological Engineering program, since it provides a holistic idea about each work-area of the future graduate, helping them choosing their future specialization. |
| Digital Signal Processing<br>*(Procesamiento Digital de Señales)* | 3rd year<br>(*sixth semester*) | This course deals with the mathematical modeling of signals and systems in real applications of signal analysis and processing. It is intended that the students understand different digital filtering techniques and how to implement them in different existing technological platforms. |
| Bioinstrumentation<br>*(Bioinstrumentación)* | 3rd year<br>(*sixth semester*) | The general objective of this course is to teach the students the concepts of measurement, the transduction process and the physicochemical mechanisms involved in the operating principles of different types of sensors. Students are familiarized with various detection technologies, correctly conditioning the obtained signals and presenting them in a useful way according to the pre-established requirements. |
| Informatics in Biology and Medicine<br>*(Informática en Biología y Medicina)* | 4th year<br>*(seventh semester)* | This course is aimed at strengthening the informatics foundations of the students applied to biology and medicine, dealing with various topics like database management systems, graph theory, data structures, |

| | | |
|---|---|---|
| | | algorithms and object-oriented programming. Students work with an applied perspective, using the concepts and tools in solving problems of biology and medicine. |
| Biomechanics<br>*(Biomecánica)* | 4th year<br>*(seventh semester)* | This course helps the students to understand the implications of human movement through the principles and methods of mechanics involving everyday situations. It seeks to problematize the analysis of movements from the biomechanical point of view and to stimulate the analysis based on the research tools of the scientific method. At the same time, it integrates several applied aspects of other areas like physical education, physiotherapy, engineering and biology. |
| Quantitative Physiology<br>*(Fisiología Cuantitativa)* | 4th year<br>*(seventh semester)* | This course seeks to develop the fundamentals of human physiology using mathematical tools, physical principles, and engineering techniques. It is intended that the student acquires the abilities to identify different types of physiological signals, model different types of physiological systems and find their response by temporal techniques, identify responses in physiological systems, represent physiological signals in the continuous and discrete frequency domain, and finally characterize and represent physiological systems in the continuous complex frequency domain. |
| Advanced Informatics in Biology and Medicine<br>*(Informática Avanzada en Biología y Medicina)* | 4th year<br>*(eighth semester)* | This course deals with providing advanced concepts of computer science like networking, database managements, computer architecture and operating systems applied to the domains of eHealth and biological systems, more with a comprehensive and platform-based approach. It aims at providing an advanced perspective of computer sciences enabling the students to solve problems in the field of medicine and biology using informatics. |
| Modeling and Simulation of Biological Systems<br>*(Modelos y Simulación de Sistemas Biológicos)* | 4th year<br>*(eighth semester)* | This course trains the students to have the ability of reasoning and analysis of biological systems through systematic learning of mathematical modeling and simulation techniques, involving the integration of the knowledge acquired in the previous stages of the program, covering branches of the exact and biological sciences. The aim for students is to achieve a correct application of the physical-mathematical concepts for the characterization of biological systems, obtaining knowledge of the fundamental properties and applications of control theory in biological systems, and a solvent management of different simulation tools and programming languages. |

One of the primary challenges in adapting the course contents to the new paradigms of virtual learning was not just to ensure the adequate learning outcome, but also to make necessary modulation of the course contents to safeguard the interesting elements of it. With this intention, the theoretical part of several courses has been reduced, introducing more practical contents and increasing applied modules. This led to a thorough change in the order of the course contents, as in the new scenario, practical contents were introduced before the theoretical aspects. It was aimed at keeping the focus on the students, to keep them at the participating end rather than just at the receiving-end of information. Especially the courses which involved some final modules of bibliographic studies, in the virtual modality, instead of keeping the module of bibliographic study at the end, it was introduced before the practical sessions, to introduce a parallel approach where the students were made familiar to the basics of literature review and scientific communications. Thus, instead of a completely independent study, the students performed guided study, where regular follow-up was performed by the professors in parallel to the course.

## 3. TEACHING METHODOLOGY AND EVALUATION STRATEGY — ADAPTATION TO VIRTUAL LEARNING

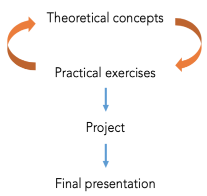
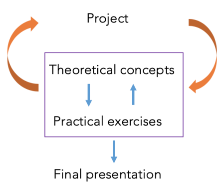
Designing the teaching methodology was crucial in this new modality so that the student-student and student-teacher interactions stay fluid. The professors of this course were carefully chosen, mostly with the objective of reflecting their transdisciplinary work in the students. Another key objective of the teaching methodology was the active participation of the students during the class hours, and a complementary ubiquitous learning beyond class-hours. This was resolved by proffering one-to-one contact for every student with the professors, which continued in the last module as well. The students had the opportunity for direct contact and continuous conversation with professors from each area of specialization, to get active support and motivation during their final project.

The evaluation of the course was designed with several objectives. On one hand it was important to assess the students' knowledge about the specific topics taught during the course. On the other hand, it was crucial to analyze the students' participation during the course activities and their skills in independent thinking, problem solving in collaboration, and scientific communication and presentation. With these objectives, the evaluation of most of the courses was designed in a two-fold procedure, where the first part is the activity of students during the course and their performance during the classes and the practical lessons. The second part was evaluated based on final examinations or presentations at the end of the course. To support and keep the students engaged during the course, special consultation classes were offered to the students beyond the class-hours to keep a close follow-up during this process [9].

Adaptation to virtual learning involved several pedagogical changes in the course including the evaluation strategies. For example, 80% attendance was a compulsory criterion for some courses; but in the new virtual modality, it was being relaxed to 60%. Moreover, a comprehensive survey was performed to analyze the technical difficulties of the students. Students without adequate technical support at home, like lack of stable internet connectivity and lack of devices to see and participate in the virtual classes, were considered and special measures were taken to make the virtual classes available to them. Especially for these students, all the classes were recorded and uploaded to the virtual classroom portal. The videos were compressed and uploaded in optimized quality as well, to assist the students with limited internet resources.

Interaction and student engagement stood as the key challenges in the new virtual modality. Synchronizing all the students was complicated due to technological disparities, causing delays in the interactions. In several courses, a pre-class Question-Answer (QA) session was conducted, which initiated group discussions between the students and professors. For example, in the introductory course of biological engineering, every single class was designed with an initial 30-minute interactive session based on the previous class' lessons (Table 2). Though the new theoretical classes were more concise, a fluid student interaction was difficult to achieve in the virtual format. The evaluation strategies of the course were also changed in the virtual system. The students were provided with periodic tasks in groups which were monitored closely by each professor and were individually evaluated through periodic classwork and homework. Especially in the courses based on informatics, the evaluation modes were changed to oral examinations followed by defense of a comprehensive programming laboratory and presentation of latest challenges and state-of-the-art of the field.

Table 2. Adaptation to virtual learning in the introductory course of biological engineering

| **Course Feature** | **Usual classroom scenario** | **Virtual classroom scenario** |
|---|---|---|
| Theoretical classes | 2 hours | 1 hour 30 minutes |
| Practical classes | 1 hour 30 minutes | 45 minutes |
| Pre-class interactive session | 30 minutes ice-breaker quiz | 30 minutes |
| Video of Class lectures | Not recorded | Group discussion and QA-session between students and professors |
| Course flow |  |  |
| Follow-up of students | During/after every class (group) | Special tutoring to groups or one-to-one video meeting throughout the week |

A key aspect that has changed completely in the virtual learning scenario is the follow-up with students. In classroom-based scenarios, follow-up was intrinsic during the classroom hours. In the virtual learning scenario, special attention is needed on the follow-up with the students. In this course, the learning curve of each student was closely monitored, in addition to one-to-one video meetings with each student. Also, the students were divided into groups especially for the practical modules. Each group was assigned a professor especially for mentoring and follow-up of the students through a scheduled one-hour video meeting beyond the virtual-class timings.

In the informatics area in general, in which the Informatics in Biology and Medicine and Advanced Informatics in Biology and Medicine courses are involved, the courses followed the line of placing a higher emphasis on practical modules over theoretical concepts. It was decided to continuously and individually monitor each student. The evaluation of the courses, which consists of carrying out defined tasks, had greater flexibility from the point of view of delivery times, in order to better adapt to the times of the students.

Regarding the Bioinstrumentation and Signals and Systems area, the courses involved (Circuit Theory, Electronics 1, Bioinstrumentation, Signals and Systems and Digital Signal Processing) faced some of the strongest challenges with respect to other curricular units at the time of their virtual adaptation. These difficulties were associated with the practical part of the courses, which involve the use of laboratories and its supplies, and the regular interaction between professors and students during the hand-on sessions.

In the case of Circuit Theory, the implementation of electronic circuits occurs in two stages, on one hand the implementation of circuits in laboratories throughout the entire course, and on the other hand the implementation of an integrating and acquisition-oriented circuit of biological signals as a final project. The laboratories were approached using simulators, which although it had the disadvantage of the loss of tangibility of the circuit assembly, were corrected at the time of the final project, in which the implementation of real circuits was carried out. The final project, although it suffered a delay in adaptation due to the initial use of simulators, it had positive results with respect to the face-to-face mode, and the hands-on activities was maintained through the use of an all-in-one USB oscilloscope and instrumentation system developed by Analog Devices. Each student received a kit at their home containing said system and all the necessary supplies for the safe implementation of the required circuit, which allowed each student to have their own laboratory at home, with a strong virtual teaching support. The fact of teaching the course virtually in its entirety implied a clear reduction in the class-hours, since previously the course was taught in three different cities spending a lot of time in synchronization. This reduction of class-hours allowed the professors to take advantage of that in adding hours of interaction to answer questions and indulge into more practical activities with the students. Overcoming geographical barriers, all students were able to take classes simultaneously in a synchronous way, without having to depend on the physical presence of the professor. In the case of Electronics 1, it had quite similar challenges of Circuit Theory when implementing circuits in laboratories. In this case, the hands-on activities were given throughout the whole course using the approach of having a laboratory at home and a strong teaching support via virtual modes. In the case of Bioinstrumentation, the adaptation of practical laboratory work to electronic circuit simulations using the LTSpice platform in conjunction with Python programming tasks. Although it is considered that both modalities (implementation and simulation) are complementary, in this virtual edition of the course, simulations were chosen for reasons of logistics and security, as well as to allow a good transfer of theoretical concepts applied to a specific practical problem. In addition to this adaptation, synchronous virtual encounters have gone from being long classes concentrated in a single day to shorter and more dispersed classes, achieving a more beneficial schedule, not only in terms of student learning but also teaching by teachers.

In the courses belonging to the Signals and Systems area, the circuits and practices implemented in the laboratory were also carried out through the use of simulators or by sending each student (the physical materials they needed for the practical modules, like Arduino, cables, protoboards, components, etc.).

The integrative courses (the workshops) faced the need for laboratory instances or laboratory tools. Those laboratories that could be implemented at home by sending kits with materials were made in this way, while those that involved laboratories with heavier equipment (Biomechanics) had to be replaced by videos of the practical sessions performed by the professors. The rest of the laboratory was done using kits, similar to the other courses.

Among the courses in the core biological engineering area (Quantitative Physiology, Models and Simulation of Biological Systems and Biomechanics), only one of them, Biomechanics, presents laboratory modules which were compromised in the virtual modality. It is related to the challenges like heavy instruments that could not be moved from the laboratory. So, in the virtual mode, the practical lessons were replaced by videos of the practical modules performed by the professors. The rest of the courses involved practical exercises with the use of computational tools, so it was adapted easily to the new modality. In the case of these courses, they experienced a reduction in the general workload of class-hours, in order to be able to dedicate more time to practical instances and consultations, with an emphasis on close individual monitoring of students.

## 4. COURSE RESULTS AND IMPACT

The Biological Engineering program at the University of the Republic since its inception in 2014 was based on the foundation of dynamic adaptability to changes, pertaining to syllabus, research-lines etc. For this reason, almost all the courses pass through a periodic reengineering by updating the course contents and teaching methodology, as well as the professors involved in the course. With the introduction of virtual modality in March 2020 due to COVID-19 pandemic, 100% of the courses were shifted to the new paradigm.

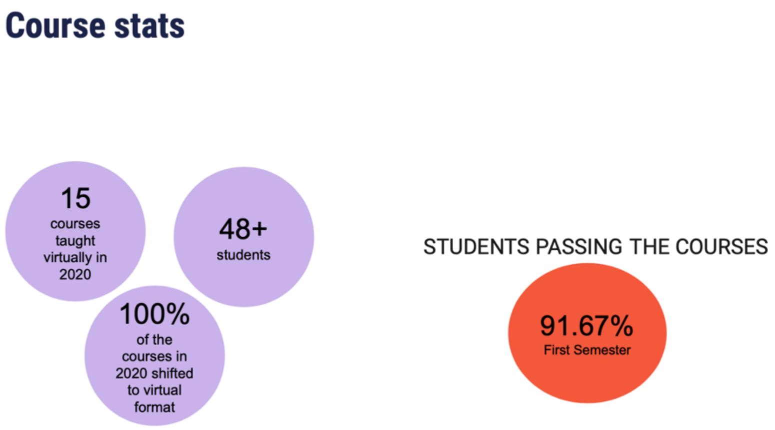



**Figure 2.** Key stats of the courses taught in 2020, Department of Biological Engineering, University of the Republic *(Universidad de la República)*, Uruguay

Throughout the entire period of virtual modality, the key objectives of the courses were met with respect to the expected outcomes. During the course, the students engaged in active learning during class-hours and peer-learning beyond the class-hours, involving active conversation with their peers and also with the professors of the course. In the new virtual paradigm, students were offered more independence in their studies coupled with strong guidance and follow-up. Throughout the theoretical and practical modules, students were exposed to a complementary approach to concepts and applications, especially illustrating real-world scenarios in a wide range of areas.

Throughout the entire program trajectory, special attention was put on the students to make them develop scientific communication and presentation skills. Especially during the virtual instances, the students were made familiarized with the virtual presentations where they were encouraged to present their work. In addition, the students engaged in virtual science outreach activities in the university, including the annual science and engineering fair *(Ingeniería de Muestra)* which was held virtually in 2020, as the students presented their projects, prototypes as well as their preliminary findings of their research.

With the change of the course paradigm to virtual platforms, it was important to evaluate the impact of the change from a comprehensive point of view, and a survey was performed on the professors on this theme. The objective was to analyze the new virtual format of the courses and consider the shortfalls or issues during the process to resolve the issues. 93% of the professors evaluated the shift to virtual modality good. Several professors pointed out that the cumulative class-hours in the virtual courses have been more than the standard course. Despite the effective class-hours being reduced, the virtual modality of the course added extra student engagement opportunities like one-to-one follow-up, and group-mentoring, making the total course-hours more than the pre-pandemic situation. In this respect, 86% of the professors indicated a significant increase in their workload compared to the previous course format (Figure 3).

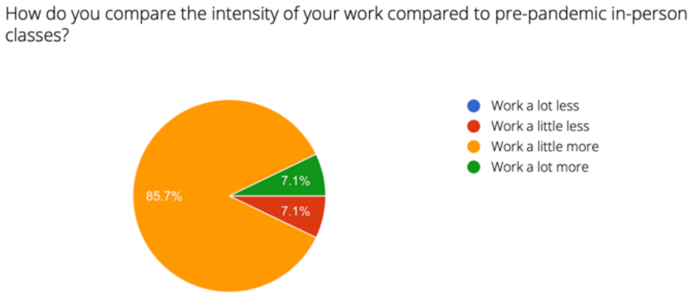



**Figure 3.** Survey of professors — Department of Biological Engineering, University of the Republic *(Universidad de la República)*, Uruguay

Special care taken in the preparation of the materials prioritizing student engagement in a virtual format tantamounted to the increase in workload. Also, this affected the distribution of work, as professors spent more time on the preparation of courseware and student-interaction than the actual class lectures (Figure 4). This was recognized by 90% of the students, who positively opined about the increase in the intensity of professors' work and dedication toward the course compared to pre-COVID-19 times [9].

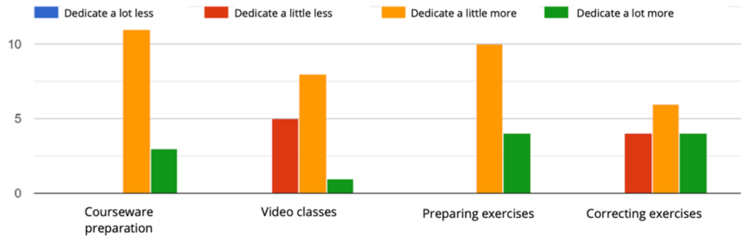



**Figure 4.** Professors on time-dedication in courses — Department of Biological Engineering, University of the Republic *(Universidad de la República)*, Uruguay

With the new virtual modality, a key challenge was the technological disparity prevalent within the students, making it difficult to follow the course in a similar pace or form. Several measures like providing video-recordings (optimized quality) of classes and one-to-one sessions were taken to allow students with limited technological resources to follow the course. Also, all the professors acknowledged a disparity among the students with respect to adaptation to the new paradigm leading to more student-issues than before. The lack of face-to-face meetings and performing the group projects virtually was a substantial component of the student issues when working in groups. Interestingly, all the professors indicated that, despite having difficulties in adapting technologically to the virtual modality, the students adapted adequately to the new paradigm over a period of two months. In the perspective of professors, the availability of technical resources to impart virtual classes was surveyed (Figure 5), which showed somewhat satisfactory level of availability.

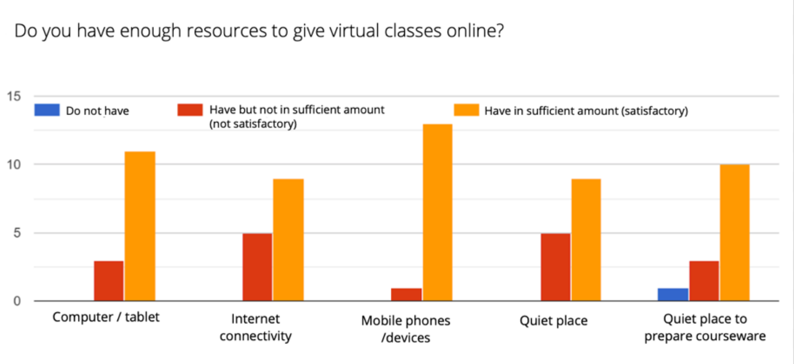



**Figure 5.** Availability of resources to professors — Department of Biological Engineering, University of the Republic *(Universidad de la República)*, Uruguay

Though the professors are divided on whether the course should go back to its previous form after the pandemic (60% no, 40% yes), all the professors agreed to incorporate more multimedia materials in the courseware to enhance student engagement. However, the survey showed a positive progression of the adaptability of the virtual teaching tools in the professors.

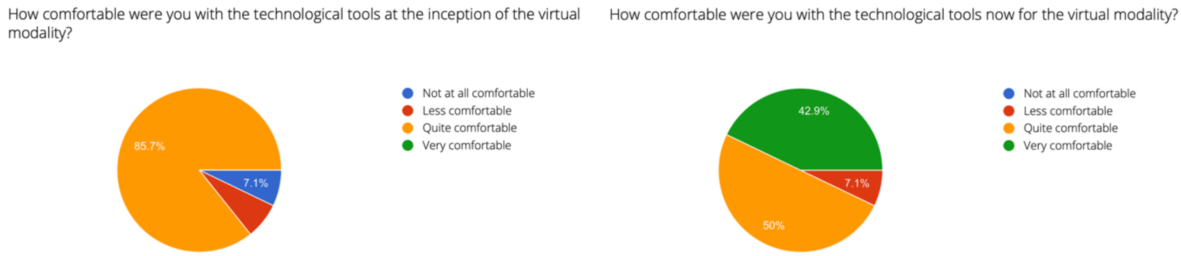



**Figure 6.** Professors on adaptability to virtual tools — Department of Biological Engineering, University of the Republic *(Universidad de la República)*, Uruguay

The impact of special follow-up in the new learning modality was another important factor to analyze especially from the students' perspective. The professors of the course have emphasized the value of one-to-one follow up with the students since most of them do not turn on their cameras during virtual classes (95% of the students expressed it should not be compulsory for them to turn on video during live virtual classes); the personal follow-up was therefore important to connect actively with the students. The professors also noted that the difficulties in working in groups occurred more in the new virtual setting for the course than the previous classroom-based versions. With respect to the process of learning in the new virtual format, in the introductory course of biological engineering, 58% of the students expressed a satisfactory level of learning, whereas 26% and 16% of the students expressed high and low levels of learning respectively (Figure 7).

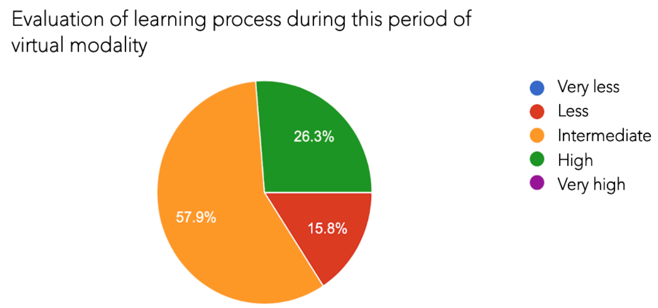



**Figure 7.** Virtual learning process — Biological Engineering Workshop 1 at the University of the Republic *(Universidad de la República)*, Uruguay

However, the students have expressed their issues with the practical modules in the virtual format. The practical lessons are given through video recordings and the students expressed their preference for classroom-based live practical sessions, since most of the practical elements of the course were meant to be performed in a classroom, using physical devices. In addition,average performance of the students has been analyzed comparing the performance in 2019 and with virtual modality in 2020 (Figure 8), to analyze the impact of the change to virtual courses during the COVID-19 pandemic, and how it affected the grades.

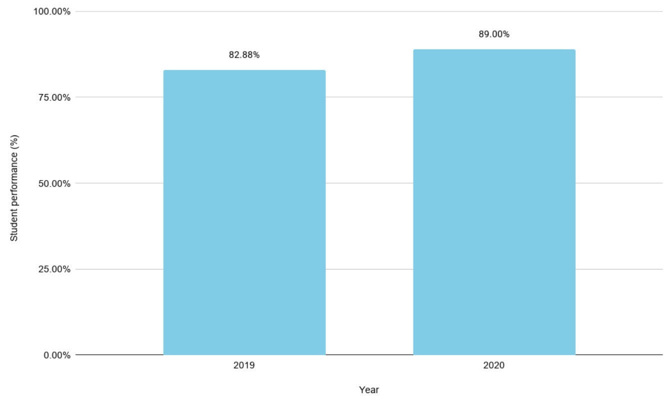



**Figure 8.** Performance of students: Years vs Average score of students in percentage — Department of Biological Engineering, University of the Republic *(Universidad de la República)*, Uruguay

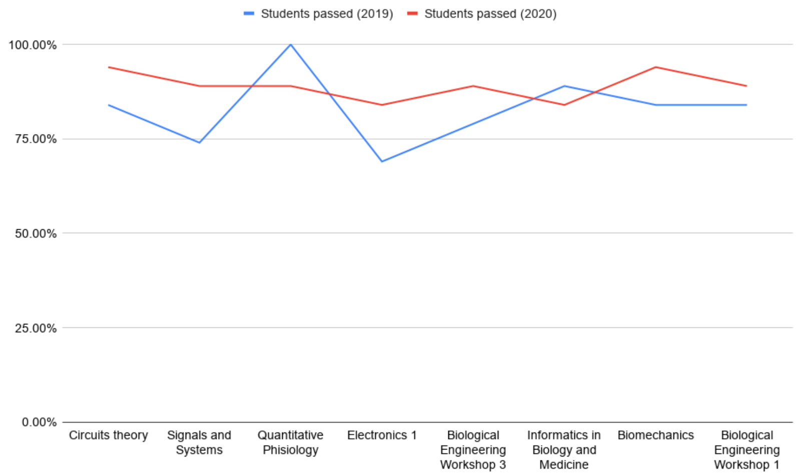



**Figure 9.** Performance of students: Course-wise scores of students in 2019 and 2020 — Department of Biological Engineering, University of the Republic *(Universidad de la República)*, Uruguay

Based on the progression of student performance, interestingly, even in 2020 with the change to a virtual modality, student performance didn't decline, moving to 89% compared to 83% in the previous year 2019. Also, in all the courses taught in the first semester of 2020, the students maintained a score of 75% and above (Figure 9), which indicates a comparatively higher performance than the last year.

## 5. DISCUSSIONS AND FUTURE SCOPE

Many countries across the world are reviewing their scientific training careers at the university-level and the way in which the new pedagogical paradigms are applied [10]. Especially at the regional level in South America, the academic sector of biological engineering has always suffered a large gap between knowledge and innovation. As most of the real-world problems and projects in this domain belong to the Pasteur Quadrant classification [3], innovation takes a key role in this. This poses an ongoing holistic challenge in the context of pedagogy and teaching methodologies, to engage students in new ways of acquiring knowledge, communicating and collaborating on a par with the global community, blurring the boundaries of each field and delving into a transdisciplinary space. The undergraduate program of biological engineering at the University of the Republic *(Universidad de la República)*, Uruguay has been designed with a transdisciplinary approach coupling knowledge, innovation and real-world problem-solving skills. With the advent of COVID-19 pandemic, all the courses taught in 2020 had to be shifted to virtual setting, posing serious challenges to the pedagogical aspects of the courses. However, through a fast and adaptive change in courseware, evaluation strategies and teaching methodologies, a high level of student-performance was maintained, even with improvement compared to the last year. With respect to biological engineering, such strategies would be relevant and useful to similar biological engineering programs in the regional and international level as the issues faced during the shift to virtual setting are often quite similar in several universities across the world [5].

However, it has been observed through the experience of this course that such courses need a fast and regular update to their knowledge element to keep up with the state-of-the-art while overcoming the challenge of ensuring the ease of study at the same time. There is also a need for professors working in transdisciplinary areas to share their vision to new students in order to engage them with research and innovation right at the beginning of their university program and supply them with the necessary transferable skills to solve real-world problems. With the restructuring of the biological engineering courses into a virtual format due to the COVID-19 pandemic, several aspects of the teaching-learning paradigm changed, especially highlighting a strong focus on enhanced student engagement during live virtual classes and thorough personalized follow-ups with the students. The new outcomes from the virtual setting point to a need of reengineering the existing learning paradigms and adapt more toward blended learning [9]. With the changing direction of pedagogy and research across the world, it is quintessential to adapt university courses to the same, promoting an environment where the scientific and engineering disciplines merge and the learning methodologies lead to a ubiquitous learning [4] environment.

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