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# Industrial Processes Online Teaching: A Good Practice for Undergraduate Engineering Students in Times of COVID-19

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**Abstract:** The COVID-19 pandemic required higher education institutions to change the modality of face-to-face to online learning overnight. Adaptations were needed, particularly in industrial process training in Chemical Engineering and related careers. Students could not access companies and industries for internships or industrial visits, intended to allow undergraduate students to observe the process engineers' work in professional spaces. This paper describes a pedagogical strategy to overcome this limitation. Here, we report an approach applied in an Industrial Processes course, with students from the 8th to 10th semesters and alumni, from the undergraduate Petrochemical Engineering program at Yachay Tech University (Ecuador). In this course, the students developed group projects involving an industrial process analysis focused on economic sectors of interest in the country. The projects also included a revision of official figures and statistics on production data, consumption, and perspectives of the different markets. The execution of these projects promoted students' active participation through technical discussions by exchanging ideas. A high level of attendance at synchronic classes reflected a high motivation. Through feedback and interviews, the students' comments confirmed the relevance and value of the strategy applied in the course.

**Keywords:** industrial processes; industrial training; process engineering; problem-based learning; online modality; COVID-19 pandemic



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## 1. Introduction

The training of undergraduate students in engineering—in different disciplines—involves conceptual, practical, and industrial process components. In the specific case of Chemical Engineering and related areas, conceptual training is provided mainly in courses on Fundamentals of Chemical Engineering, Unit Operations, Transport Phenomena, and Chemical Kinetics. Practical training is obtained both in laboratory activities and through the development of 3D scale models representing the topics studied in theory classes. Training in industrial processes can be conducted through elective courses that address industrial process analysis and process design or through internships and industrial visits carried out by students directly in companies and industrial facilities, as their first experience in a real-work context [1,2]. In general, industrial tutors' perception of the internships as pedagogic tools is good or very good [3]. Currently, the recruitment of new professionals in companies is commonly based on their performance during internships. Moreover, industrial visits are an excellent practical pedagogical tool that allows undergraduate students to expand their vision about the development of engineers in professional spaces [4].

Two experienced professionals in the industrial area, Phillips [5] and Ribes [6], agreed that to achieve success as a professional in the industrial sector, three elements of interest are necessary: (i) a strong understanding of engineering fundamentals, (ii) the application of that knowledge in real-world cases, and (iii) the integrating vision of the work environment. It is paramount that engineering students acquire these skills early. Project-based learning in real scenarios is implemented worldwide to complement the training of engineering students in the industrial component [7–10].

One of the challenges of teaching in Chemical Engineering programs and related careers in times of the COVID-19 pandemic is training in industrial processes [11]. Online learning and distance learning are challenges for STEM (Science, Technology, Engineering, and Mathematics) academic programs, with the additional difficulty of making changes overnight. An advantage of the online modality is that it allows the professor to record classes, and later, students can view them repeatedly [12]. However, an online modality presents some deficiencies; it considerably decreases the interaction and collaboration between students and professors and among the students themselves. It also minimizes group work and discussions. Internet connection problems can occur [13], forcing students to be absent from synchronic classes or prioritize recorded classes [14].

Due to the collective isolation measures taken worldwide to deal with the COVID-19 pandemic, many of us went into prolonged confinement, being forced to carry out academic, professional, and work activities from home. This situation caused companies to suspend internship programs intended to receive students or carry out industrial visits. In some cases, students carrying out internships at companies and factories at the time were untimely suspended. Different strategies have been proposed in universities and polytechnics worldwide to provide high-quality training in the industrial component [15], "either by offering students alternative electives online or by carrying out various forms of project work in their home environment under the online guidance of a tutor" [16]. Additionally, virtual reality usage in training for the chemical industry has been proposed [9]. Nowadays, the terminology "emergency remote teaching" has come up as an "alternative term used by online education researchers and professional practitioners to draw a clear contrast with what many people know as high-quality online education" [17]. With the appearance of new variants of COVID-19 [18], it has been necessary to offer educational strategies that guarantee the training of students at different levels of education, with high-quality standards [19], including the online modalities [20–25] and blended learning [26].

Yachay Tech University (YTU) is a public higher education institution located in Ecuador, created in December 2013, where scientific and technological undergraduate programs are taught in STEM areas. The programs have a duration of five years (10 semesters). To graduate, students must complete an undergraduate thesis focusing on applied research or developing case studies on an industrial scale. Currently, this university has five cohorts of graduates who stand out for their excellent training, which has allowed them to successfully apply for graduate programs in countries in Europe, the Americas, and Asia. More details about YTU can be found in Ricaurte and Viloria [27]. Before the COVID-19 pandemic, the YTU organized technical visits to different companies with the intention that the students could directly observe industrial activity, learn about the value chain, the role of process engineers or plant engineers, and the applicability of the theoretical foundations learned during the undergraduate program. The industrial sectors included in the visits involved cement, textile production, sugar cane processing to obtain sugar or bioethanol, metalworking, and oil and gas.

To the best of our knowledge, educational strategies related to teaching in industrial processes for undergraduate engineering students in response to emergency remote education and the emerging need for practical courses are not reported. Therefore, this study presents a pedagogical proposal for undergraduate students' training in industrial processes in times of COVID-19. The motivation was to learn about different industrial processes from a comprehensive vision focused on the industrial activity in the country, which allowed them to complement their training in Chemical Engineering and related areas in times of pandemic, where access to companies and industries is limited for internships or industrial visits. Videos were presented on different processes to immerse

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data supporting the findings of this study are available from the corresponding author, M.R., upon reasonable request.

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## Appendix A Interview Questions

Q1. Did the project help you better understand the concepts of industrial processes and process design?
Q2. Was this project helpful in demonstrating the role of process engineers or plant engineers?
Q3. Was this project helpful in understanding complementary information related to a chemical engineering process, such as economic indicators?
Q4. Was this project valuable in understanding different industrial processes of interest to Ecuador and understanding its potential?
Q5. Since you worked in a team, did the team's interaction help you improve your learning?
Q6. How were the learning and formation you received in the Industrial Processes course during the COVID-19 pandemic?
Q7. What else do you want to say about distance learning in industrial processes?
Q8. How was the strategy applied to develop this class and its characteristics compared to the other courses you took the semester?
Q9. Only for alumni: Since you are already a former student from Yachay Tech University, what was your motivation to take this class?

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