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Reflections from education practice: Learning experiences for education in industrial engineering in the post-pandemic world

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Abstract. One of the main challenges arising from the COVID-19 pandemic was providing continuity in education. This article focuses on the provision of higher education in the discipline of Engineering and its related academic programs, analyzing the limitations and challenges imposed by the pandemic and considering future implications. To ensure high-quality education, it was necessary to sustain active, experiential, student-centered learning experiences that develop skills despite the remote interactions, frequent technological deficiencies, and limited educational resources. Thus, drawing on initiatives from the Massachusetts Institute of Technology Supply Chain And Logistics Excellence network for Latin America and the Caribbean (MIT SCALE LAC), this article explores efforts by private universities in Bolivia, Mexico, and Peru to maintain active learning experiences during the pandemic, with a link to the contemporary challenges faced by organizations, communities, and the wider society in which students live. Finally, the article proposes a concept map

based on six dimensions to guide the design and reflection of learning experiences with a post-pandemic perspective.

Keywords: active learning, learning experiences, engineering education, Latin America, COVID-19 crisis.

1. Introduction

In recent years, universities have faced challenges related to the relevance of their curricular content, their practical utility, and their impact on students' future professional lives (De Vries & Navarro, 2011). This has translated into a need to develop students' technical and professional skills as well as their ability to deal with real-life situations in a changing, complex, and uncertain environment (Gibbons, 1998; Organization for Economic Cooperation Development, 2018; Vargas & Callata, 2021).

Moreover, university students and their families expect higher education to contribute to employability and professional growth, and to offer a financial return on their investment and effort (De Vries et al., 2011; Gaudin & Pareyón, 2020). Finally, universities are expected to provide high-level education through in-person, remote, or blended formats (Vegas, 2020; Yangali et al., 2021). All this requires substantial changes in higher education to improve the efficiency and relevance of learning and to ensure recent graduates are better prepared to enter the job market while also contributing to society and their communities (UNESCO, 2019; Anaya et al., 2021; Luna, Hidalgo-León, & Chong, 2021).

At the same time, over the last decade fields such as genomics, robotics, the internet, and nanotechnology have transformed every sphere of human activity (Chong & Quiliche, 2021), including higher education (Tecnológico de Monterrey, 2018). These developments pose additional major challenges for learning and education that today's students must address in order to become better-trained professionals (Yangali et al., 2021).

However, since the outbreak of the COVID-19 pandemic in March 2020 (WHO, 2020), these challenges, far from being resolved, have grown in scale and complexity at all levels and spheres in different countries and societies (Ugarte et al., 2020). This has been apparent through different global or regional forums such as the 26th United Nations Climate Change Conference (COP26) in Glasgow, the 2022 World Economic Forum (WEF) Annual Meeting in Davos, and the 6th Summit of the Community of Latin American and Caribbean States (CELAC) in Mexico, 2021. The WEF's annual Future of Jobs Report noted that the types of occupational skills and knowledge required have changed dramatically during the pandemic (World Economic Forum, 2020, 2021).The pandemic revealed the complexity of the problems, the uncertainties, the resilience, and the inequalities among the communities that were facing this new situation. This situation triggered the need for swift technological adoption, which caused problems in relation to digital transformation, technological access, inclusion, and equity (Anaya et al., 2021; Rentería et al., 2021), among others. Universities

had to respond to these new trends and requirements by assuring students developed the necessary new skills and abilities (Luna et al., 2021; Regal et al., 2021). This led to a new understanding of teaching and its impact on students' current and future education.

To continue in this direction in the post-pandemic era, universities in Latin America and the Caribbean must take up the mantle of changing their visions, models, and practices (Luna et al., 2021). They require a perspective that goes beyond traditional educational approaches and promotes the use of high-value teaching methods amid the new contexts and conditions of learning, communication, and social interaction (Machuca et al., 2021). To confront this new reality, they must promote educational innovation aligned with humanity's major challenges and necessities by developing learning-related conceptual frameworks, experiences, and activities. In the case of Engineering education (Luna & Chong, 2020), this entails a skills development approach for the resolution of complex problems by way of technological solutions. But the discipline faces additional challenges concerning access to laboratories, workshops, and technological resources for practical learning and experimentation (Chong & Luna, 2019; Luna & Chong, 2021).

Indeed, for Engineering and related fields that center on sociotechnical systems—the main focus of this study—educational innovation and leadership (Machuca & Chong, 2019) needs to take into account ethical and sustainability implications and restrictions involved in the resolution of complex problems, encompassing multiple perspectives and decision-making in the uncertain conditions of the new reality (Aguilar, 2020; Dorin, Chong, & Machuca, 2020). Engineering education involving the management of operations, production, logistics, and supply chains must respond in similar terms to the pandemic and to an uncertain and changing future by creating value and knowledge for organizations, communities, and society in general (Salinas-Navarro, Garay-Rondero, & Calvo, 2020).

The objective of the present study is to propose a concept map of educational leadership and innovation for the development of students' skills through active and experiential learning that is relevant to the pandemic-era challenges in Industrial Engineering and its related disciplines. Although this study deals with the general context of global education, it focuses primarily on Latin America and the Caribbean given the authors' academic work with the MIT Supply Chain And Logistics Excellence network for Latin America and the Caribbean (MIT SCALE LAC)—led by the Center for Transportation and Logistics at the Massachusetts Institute of Technology—and its member universities, which aims to develop students' knowledge and skills

in order to improve the competitiveness of Latin American organizations and train the change leaders and problem solvers that the region requires.

This study is divided into five sections. In the next section we discuss learning requirements in the new context of the COVID-19 pandemic as well as how the requirements related to skills development and learning activities have been altered to respond to the educational needs of remote environments. In the third section we comment on the initiatives taken by Latin American member universities of MIT SCALE LAC for the provision of undergraduate academic programs in Industrial Engineering in particular—though we also take into account Systems Engineering, and Enterprise Engineering programs—in relation to the areas of operations, logistics, and supply chains. In the fourth section we draw on the lessons learned from these initiatives to present and discuss a concept map for the conceptualization and design of teaching and learning activities for the post-pandemic world.

2. Learning requirements in remote environments during the COVID-19 pandemic: context and challenges

In recent years, new higher education approaches oriented towards innovation or educational leadership have been proposed, drawing on a range of perspectives; some have taken strategic approaches to educational quality, accreditation, inclusion, and employability (Santana & Royer, 2020), while others are aimed at improving teaching activities and educational relevance through the likes of skills-based, experiential, and challenge-based learning, which bring real-world experiences into the classroom (Observatory of Educational Innovation–Tecnológico de Monterrey, 2017). Other educational strategies, such as gamification, the flipped classroom, and educational technologies, have bolstered students' interest and motivation, promoting active learning and responsibility regarding their studies (Garris, Ahlers, & Driskell, 2002). Examples of such approaches have emerged in different disciplines and geographical regions, at events such as the QS Reimagine Education conference, the Institute of Electrical and Electronics Engineers (IEEE) educational leadership conferences, or those sponsored by associations such as the Institute of Industrial and Systems Engineers (IISE). These experiences have been characterized primarily by experiential learning activities and challenges in various in-person educational formats and settings (Chong & Luna, 2019; Luna & Chong, 2020; Salinas-Navarro et al. 2021; Salinas-Navarro & Garay-Rondero, 2021).

However, since the declaration of the global COVID-19 pandemic in March 2020, all global communities have been forced to confront a new

reality. To curb the spread of the virus, governments applied various isolation or confinement measures, prompting changes in everyday activities and forms of socialization in areas such as transportation, work, shopping, entertainment, and teaching–learning (Cohen, 2021).

Universities pursued different remote teaching options during the pandemic, including web-based teaching tools, online quizzes, video demonstrations, and software simulations, among others (Skulmowski & Rey, 2020). However, certain problems and constraints have hindered the learning and preparation of professors and students (Burki, 2021). For example, professors struggle to design courses and offer the necessary hands-on experience without direct access to the equipment and data required for lab work (Bangert et al., 2020; Luna & Chong, 2020). The multiple challenges for professors have concerned the teaching-learning process itself, interaction with technological tools, the advantages and disadvantages of remote education, internet connectivity (for professors and students), management of uncertainty, empathy with students, resilience in the face of the pandemic and its consequences for the entire community, and provision of a friendly, appropriate, inclusive, and flexible class environment (Dhawan, 2020; Luna & Chong, 2021).

It is thought that Engineering students are better able to learn complex concepts through laboratory experiments or direct immersion in situations related to their studies, in that practical work is crucial for the development of problem-solving and decision-making skills (Christian, McCarty, & Brown, 2020). However, restrictions on social interaction and access to educational facilities and resources have affected students' learning experiences by forcing either the closure or the virtualization of laboratory work and innovation through home-based experimentation (Mpungose, 2020; Kapilan, Vidhya, & Gao, 2021). Thus, the effectiveness of the interactions between professors and students was drastically impaired amid the total reliance on remote virtual platforms (Buheji, Ahmed, & Jahrami, 2020).

While virtual labs or simulators can help students overcome these problems (Sinclair, 2008), issues can arise when the software does not cover learning objectives or address abstract theoretical situations (Dhawan, 2020), or when professors lack the time, knowledge, or institutional support and financing to develop these resources. Likewise, applied research, with its associated fieldwork and business visits, required new educational alternatives to improve learning capabilities and overcome the limitations or outright impracticability of these activities during the pandemic (Burki, 2021; Code, Ralph, & Forde, 2020).

This new reality calls for appropriate remote hands-on activities to bring about meaningful and lasting learning (Lalley & Miller, 2007; Freeman et al.,

2014). The alternatives implemented must entail real or simulated situations in which students are motivated and actively learn by doing with the aid of technology in learning spaces (Benkert & Van Dam, 2015). Learning must also be connected to current problems, respond to the changing needs of society (Sen, 1997, 2000), and meet students' daily or future career requirements given the new reality of the pandemic and its potential repercussions (Gibbons, 1998; Bruner, 1971; Stabback, 2016).

As part of the initial exploration of the effects of the COVID-19 pandemic on the delivery of practical courses, in April 2020—soon after the outbreak of the pandemic—we administered a survey to 66 laboratory instructors based in four regions of Mexico and pertaining to the Industrial and Systems Engineering program at Tecnológico de Monterrey. The survey explored the transformation of four laboratory courses during the pandemic. It contained nine questions about the course name and code, years of teaching experience, type of employment contract, geographical location, and changes made in the courses, as well as the barriers faced, actions taken, and instructors' perceptions about the development of their courses. The survey found the following:

- A total of 46 instructors opted to transform courses through implementation of integrative learning activities. In addition, 20 respondents noted a change in the weighting of learning activities and exams, and 6 noted a change in the use of educational technology.
- The greatest barrier to learning identified was poor internet connection, identified by 26 of the instructors. Also notable were problems with institutional design, cited by 14.
- The actions taken corresponded to the development of new learning resources, (42 instructors; institutional training, with a response frequency of (32 instructors); and collaboration with colleagues, (9 instructors).
- The opinion of instructors on a Likert scale (1=poor; 5=excellent) was 4 (good), (50 respondents).

Based on these results, it can be concluded that educational innovation efforts to motivate and develop student skills effectively amid the current restrictions requires the use of technology and the setting of real conditions for problem-solving in learning activities.

Before the pandemic, educational innovation prioritized the use of active and experiential learning strategies, methodologies, and resources based in the classroom, which are more effective and long-lasting than passive approaches (Lalley & Miller, 2007; Paechter & Maier, 2010). However, at present, new types of learning experiences, involving remote or active

distance approaches, are required due to limitations to travel and social interaction (Code et al., 2020).

Amid the increased uptake of remote education, the main focus of educational innovation is now blended and asynchronous learning involving the use of simulators, remote or home laboratories, online learning content and resources, and the use of information technologies and mobile applications (Guerra & Gopaul, 2021). The goal during the pandemic has been to keep centers of learning open and operational despite the multiple barriers or obstacles posed by social distancing. However, there have been substantial challenges due to the limited availability of technological resources for teaching and learning, the personal difficulties faced by students and educators in the new context, and the design of learning activities conducive to remote interaction.

Despite this, students' learning and skills development objectives must continue to be fulfilled so that their training and future professional expectations can be realized. In this regard, it is necessary to rethink students' experiences in traditional in-person learning spaces that have now shifted to remote or blended formats, with synchronous or asynchronous interaction and communication options, different levels of interaction with professors and classmates, and a wide-ranging learning infrastructure for use outside the classroom (Salinas-Navarro et al., 2019). In addition, learning activities that motivate students and spark their interest in situations that are relevant, oriented to the real world, suited to practical activities, and aligned to students' realities are required (Salinas-Navarro & Garay-Rondero, 2020, 2021; Salinas-Navarro, Garay-Rondero, & Calvo, 2020; Salinas-Navarro, Alanis-Uribe, & Da Silva-Ovando, 2021). Therefore, experiential and active learning experiences must be provided in a range of learning space for the development and assessment of students' skills.

2.1 Redefining higher education during the COVID-19 pandemic

In the first half of March 2020, actions were taken around the world to reduce the impact of COVID-19, including measures aimed at reducing social contact and various confinement models (Aguilar, 2020). Latin America's first cases of coronavirus were detected in the first half of March 2020 (Araujo-Banchon et al., 2020). Not long after, several national governments announced the suspension of classes in schools (Peru, 3/11; Bolivia, 3/12; and Mexico, 3/20) followed by the decree of a state of emergency and the implementation of strict confinement measures (Peru, 3/16; Bolivia, 3/26; and Mexico 3/31).

From that moment on, many universities worked on drawing up remote work plans for their academic activities (Vargas & Callata, 2021). These

universities anticipated a blended modality (in-person and remote) to accommodate the reduction in classroom capacity. For example, the Universidad del Pacífico in Lima, Peru, began trialing Blackboard Collaborate, Skype meetings, and the virtualization of laboratories, which proved the biggest challenge. At the Universidad Privada Boliviana in Cochabamba, Bolivia, classes migrated to Zoom with the aid of the Moodle platform. The virtualization of the university's laboratories was critical and complex, so it was decided to delay these measures until greater student security could be assured. Unfortunately, the lack of a clear timeframe for the return to an in-person modality hindered many activities in Engineering and related degree programs. Meanwhile, Tecnológico de Monterrey also migrated to a remote synchronous model using the Zoom and Canvas platforms, and gradually integrated remote laboratories, seminars, and workshops into their classes and other activities with the aim of assuring their quality. However, by the beginning of 2021 these three universities had implemented dual systems, with one blended course modality and another in-person one with smaller class sizes due to distancing.

This situation has had implications for educational quality (Vargas & Callata, 2021), and for students' inclination to continue their studies in these circumstances (Vegas, 2020). Universities have continued and will continue to migrate to other virtual tools and systems (Martí Castro, 2003), despite prevailing limitations in terms of professors' familiarity with tools and adequate student access amid hardware, software, and connectivity limitations. The initial challenge was to create value through remote classes, and then the challenge was to ensure the same value was created regardless of whether classes were remote, in-person, or blended (Vegas, 2020).

As part of this value creation, educational activities were adapted to assure an effective transition and to sustain the quality levels of students' training (Aguilar, 2020; Du et al., 2020). To help understand this adaptation process, between October and November 2020 the Universidad del Pacífico prepared a survey, which was ultimately distributed to four Peruvian universities, to measure students' satisfaction and intention to continue with remote classes (Machuca et al., 2021). The survey, completed by 126 Engineering students at the four universities, measured satisfaction with remote classes, perception of value, adaptability, social influence, and other areas in line with expectation confirmation theory (ECT) (Ramayah, Ahmad, & Hong, 2016; Chiu, Cho, & Chi, 2020). Table 1 presents the values for each dimension on a scale of 0 (no or little impact) to 5 (maximum impact).

Table 1
Dimensions of ECT

Dimension	Average	Standard deviation
Continuance intention (CI)	3.3730	0.81170
User satisfaction (US)	3.1746	1.04368
Perceived usefulness (PU)	2.7341	0.79734
Perceived adaptation (PE)	2.9153	0.92466
Effort expectation (EE)	3.6567	0.76075
Social influence (SI)	2.7540	0.96436
Trust (T)	3.2513	0.80850
Acceptable behavior (SN)	3.4709	0.68413
Trust sensation (TS)	2.8466	0.94718

Source: Machuca, J., & Chong, M. (2019).

The results attest to a measure of satisfaction in the remote environment, but with some areas for potential improvement (Gupta et al., 2020). The responses with the highest score express a high degree of satisfaction with the ease of using lean management system concepts and a medium degree of satisfaction with the handling of personal information, both of which correspond to the effort expectation (EE) dimension (Sun et al., 2020). These results suggest that efforts to use technological resources should fully exploit available capacities instead of seeking alternative resources (Benkert & Van Dam, 2015). In this dimension, the responses reveal a high level of satisfaction, at 79.4%.

The intention to continue using remote education slightly exceeds the threshold for the "high" category, while satisfaction with remote education is at a medium level. This indicates that greater efforts should be made to provide satisfactory post-pandemic continuity, with emphasis on improving the communication and interaction experience. Indeed, comparison of the results of the perceived usefulness (PU) dimension shows that students are more satisfied with communication and less so with interaction. There is also a disparity regarding the intention to continue with remote education; the students who responded tended to say they would like to continue using it (3.73 on the Likert scale) but would prefer to postpone it due to a low perception of usefulness (2.73). This may be related to the circumstances of the COVID-19 pandemic, which forced all classes to go online (Vegas, 2020), and to low satisfaction with levels of social interaction given the mandatory universal confinement measures. This perception may also have influenced students' overall opinion of the remote educational experience.

2.2 New student skills in distance learning

Notwithstanding the difficulties arising from the pandemic, higher education, and Industrial Engineering programs in particular, still require skills development in accordance with the training and accreditation criteria adopted by universities. Indeed, developing and assessing skills has become more difficult amid the pandemic response measures, which have necessitated changes in the design and execution of learning experiences that contribute to these ends.

For this reason, the creation of active learning experiences has been set as an objective in the MIT SCALE LATAM, through the implementation of different innovative methodologies and initiatives by way of collaboration between the network's universities. These initiatives seek to develop specific disciplinary and cross-cutting skills that will prepare students for their professional future.

Definition of skills

To define learning skills, it is vital that professors employ good criteria when deciding how each desired skill is to be attained. According to the Accreditation Board for Engineering and Technology (ABET), Engineering students should attain seven basic skills as an outcome of their education (see https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/). In 2019, these skills were reviewed and, following recognition that some needed to be generalized and combined, they were reduced in number from eleven to seven.

Clearly, this generalization does not take into account specific skills that may be required in the new context of the pandemic, or in the development and assessment process. For instance, the complexity of defining, monitoring, and assessing skills has intensified. Skills assessment was already difficult under the traditional class format, given that it required an element of interaction between professor and student rather than just written tests (García, 2008). But assessment became even more complex after virtualization since it required virtual tools that in many cases had not been mastered by professors.

A clear example of this can be seen in the points related to problem solving and teamwork in the ABET skills classification. Previously, learning activities involving an active approach allowed for the development of skills that could be applied to solving problems in an environment through interaction with that environment. This approach was impeded from the moment that students became unable to interact actively with the object of study. To replicate the approach, teachers had to develop

virtual tools that can generate these interactions through virtual workshops, visits, talks, and other tools that bring students closer to a "real" environment. In turn, the merger of work teams is also affected by the restricted interaction between students. However, there are also some benefits: remote interaction between teams allows for multidisciplinary groups in terms not only of professional and academic background but also of geographical origin.

Beyond the requirement that professors assign the appropriate activities for students to attain the proposed skills in their course under a remote or blended format, problems can arise in motivating and preparing students to take part in remote activities (Yangali et al., 2021). The evidence shows that students experienced an increase in stress levels during the pandemic (Velázquez, 2020; Son et al., 2020; Aráoz et al., 2021), which considerably decreased their motivation for remote learning and for responding in class. These elevated stress levels are driven by both internal and external factors, which limits the likelihood of a professor calibrating all of these factors to improve student attainment (Usher et al., 2021). Rather, the complexity of these factors has forced professors to seek out new tools to overcome demotivation and stress in students (Yangali et al., 2021), while also pursuing attainment of the skills proposed for their courses.

3. Use of innovative approaches in distance learning during the pandemic

During the pandemic, efforts have been made within the MIT SCALE LAC to advance educational leadership in the region. An example of this are the efforts by private universities in Bolivia, Mexico, and Peru to provide learning experiences and educational continuity in logistics and supply chain courses. These experiences go beyond the implementation of remote instruction methods to include educational components based on experiential, challenge-based, and skills-based learning. The intention is to offer students unique and memorable learning experiences related to contemporary challenges, foster sustainable development and ties with the community, and enrich the universities' academic curricula (United Nations Organization, 2020).

These initiatives are summarized here descriptively and as illustrative examples; the intention is not to present an analysis of their academic impact, instructional design, or contribution to the different participants. This can pave the way for future research and a work agenda for educational innovation in the educational discipline of Engineering in Latin America.

3.1 Initiatives within the MIT SCALE LAC network for education related to supply chains and logistics

As a first example, it is worth examining Universidad Privada Boliviana (UPB), an institution that has developed different active learning initiatives as part of its curriculum. In Industrial Engineering, active and collaborative learning experiences were prepared for the Integral Logistics course from the start of the pandemic. Three such learning experiences were designed to bring students closer to a "real" environment using different virtual methods and tools.

Initially, in the second semester of 2020, the UPB created learning challenges focused on the beverage industry, in conjunction with the brewer Cervecería Boliviana Nacional. The task assigned to students on the Integrated Logistics course entailed preparing solutions for the company's warehouse indicators. Each group of students was expected to prepare their deliverables based on what they had learned, and to submit their assignments to the course's training partner upon completion. Given the restrictions on physical visits, the students were given the opportunity to carry out virtual visits and meetings with company employees and leaders. In these kinds of initiatives, which traditionally involve on-site field visits, students gain insights into specific industry problems by formulating practical proposals that are appropriate to the reality of the business in question. A survey administered to the entire population of 25 students on the course indicated a satisfaction rate of 82.42%.

For the following Integral Logistics course (semester 1-2021), the challenge assigned was centered on the social impact of sustainable food supply chains. To this end, the students were required to develop a plan to avoid disrupting the last mile of food-staple chains in peripheral areas of the city of Cochabamba. Students drew on interviews with and presentations from leaders from a range of food producers, in addition to the results of a survey, administered to Cochabamba residents in early 2020, about the perception of food availability in the region during the mobility and access restrictions related to the confinement measures imposed by the government (Salinas et al., 2021). Moreover, once the second wave of the virus subsided, the students were able to seek out their own primary sources, conducting interviews with actors at points of sale and with intermediaries. In addition to fostering technical skills related to the subject, the learning challenge aimed to inform students about situations that affect their environment and which can be tackled alongside industry and society. A survey of the entire group of 11 students found an approval rate of 75.41%.

Finally, in the second semester of 2021, the students undertook a joint project with Industrial Engineering students from Universidad de la Sabana

in Colombia. The aim of this project was for students to identify a perishable food supply chain and design a location and distribution network model for the cities of Bogotá and Cochabamba. This experience was completely different from those that preceded it, in that the main focus was on bringing together students from different backgrounds and cultures to work together on completing a task. This is a clear example of the opportunities that can arise with the virtualization of classroom activities. In this case, the survey recorded an approval rate of 83.23% among the 11 students enrolled.

All these initiatives are centralized under the auspices of the university's Logistics Operations Center. As well as creating experiences that approximate real-world contexts, whether industrial or social, these activities serve as seed projects that the students take up upon completion of the course. These experiences also aim to assure the scope of specific, cross-cutting and general technical skills in each of the groups within the remote learning environment. As a result, several of these assignments have already provided the basis for final degree projects, articles, or application projects.

A second case concerns the learning experiences acquired at the Social Lab for Sustainable Logistics (SLSL), an educational innovation project developed through the Novus research fund at Tecnológico de Monterrey (Salinas-Navarro & Calvo, 2019).

The SLSL integrates logistics and supply chain topics with the sustainability requirements for experiential learning in the teaching of Industrial Engineering through specific experiential formats or learning challenges, such as curricular courses, innovation weeks, full semesters, research-based courses, or final projects. The learning challenges recreate experiences related to contemporary logistics and supply chain issues in the urban areas of megacities in emerging countries, as well as their environmental, social, and economic effects on sustainability from a systemic perspective. The SLSL seeks to develop students' technical and personal skills through the study of problems in last-mile logistics, retail operations, urban freight transportation, and loading/unloading. The topics are linked to the United Nations Sustainable Development Goal 11 on sustainable cities and communities, paying particular attention to urban mobility, food security, environmental protection, waste management, energy saving, health and wellbeing, community participation, and equality and social inclusion.

Academic activities are designed in line with the ideas of experiential, challenge-based, and skills-based learning, resulting in a wide range of learning experiences to fit the corresponding educational requirements. During the pandemic, continuing with this type of experience under the constraints of social distancing was particularly challenging, and the problematic situa-

tions and relevant challenges set had to conform to the conditions of social distancing and the public health emergency.

This is exemplified by the IN2005 System Dynamics course, taught during the seventh semester (February–June 2021) of the Industrial Engineering program at Tecnológico de Monterrey's Mexico City campus. In this instance, students participated in the design of the learning experience in the second semester of 2020, helping to identify challenges related to the sustainability of Mexico City and its communities during the pandemic. Through surveys of family members, neighbors, and friends, the students explored the purchase, supply, and consumption of food. They concluded that the pandemic had an impact on food security in terms of purchase opportunities, accessibility, availability, and affordability (Salinas et al., 2021). In February 2021, the course focused on studying the performance of bodega and supermarket supply chains. The objective was to model the complexity of the prevailing situation in terms of the supply of food to households, using causal models with feedback loops and systemic archetypes to identify leverage points with a view of informing policies and decision-making. The learning experience proved satisfactory. In the students' responses to the university's student opinion survey (ECOA), completed by 11 of the 16 students on the course, the average assessment was 10.0 for methodology and learning activities, 10.0 for understanding of concepts through practical application, and 10.0 for the level of intellectual challenge (the survey utilized a ten-point scale in which 0 meant "terrible" and 10, "exceptional.")

A final case worth mentioning is that of the Value Engineering Management course, taught during the eighth semester of the Business Engineering program at the Universidad del Pacífico in Peru. This course brings together the concepts of operations with those of supply chain management (Gaudin & Pareyón, 2020). The course is taught in two sessions per week; a theory session, focusing on concepts, cases, and simulation; and a practice session, which develops the concepts and application of "The Fresh Connection" simulation game based on the roles of purchasing, operations, sales, and supply chain. From its conception, the course faced the challenge of imparting the concepts and creating knowledge through class dynamics, field work, and applied research, in line with the initiatives of the MIT Center for Transportation and Logistics. Before the pandemic, this course covered themes related to urban and humanitarian logistics. On the urban logistics side, the course employed the square kilometer methodology to the Lima districts of Lince, Jesús María, Pueblo Libre, La Molina, San Isidro, Miraflores, San Juan de Miraflores, and Comas. In turn, with regard to

humanitarian logistics, the course focused on the management of natural disasters, such as the flooding in Chosica and landslides in Carapongo, both in the Lima region, as well as the El Niño phenomenon in Paita, in the Piura region. Finally, the course deployed mixed-method research to study food security in the district of Magdalena market and pedestrian movement at the Gamarra clothes market, both in Lima city. In March 2020 the course had to be reoriented to a fully remote approach. In this context, the key question concerned how to retain the essence of the course.

In late March 2020, learning management tools such as Blackboard, Google Classroom and Teams; communication tools such as Skype, Blackboard Collaborate, Google Meet, and Zoom; and utilities such as Miro, Flipgrid, and Illustrator were explored. This gave rise to a pyramid of communication and support among the university authorities, course coordinators, professors, heads of practice, and teaching assistants. During the academic period from April to July 2020, many educational, IT, technical, personal, and other unforeseen challenges had to be faced (Gutiérrez-Moreno, 2020). For example, it was not initially taken into consideration that almost half of the students were in their hometowns and cities outside Lima (Gaudin & Pareyón, 2020), in a country with an internet penetration rate of only 60%.

In the case of the Value Engineering Management course, the IC3 methodology (integration, collaboration, communication, and trust) was implemented so that gamification could be used as an active learning strategy. Sessions were organized into set work routes for each class, where the activities to be carried out per session, as well as the resources assigned, were decided upon.

Similarly, by implementing challenge-based learning throughout the 24 sessions, synchronous and asynchronous activities were designed, with external speakers and training partners complementing the theoretical activities. To this end, deliverables for professors and students were distributed by sessions. In all cases, at the end of the course, surveys were administered to all participants. These, together with the general course assessment, were useful in evaluating the professor's performance and the quality of the activities (Gutiérrez-Moreno, 2020). Moreover, students' grade point averages served as a metric to measure the level of learning by way of different active methodologies. Student interest in the subject could also be assessed using external products such as articles and conference participation.

Table 2 shows a comparison of the experiences detailed above in the three different countries, based on the objectives, the skills developed, assessments of students, and assessments of professors. There is an apparent correlation between, on the one hand, continued fulfillment of the learning objectives

and skills development proposed by the academic programs to meet the academic quality criteria, and, on the other hand, program accreditation at the universities. Likewise, there is a common understanding of the approach to achieving active and relevant student learning in the present situation. Finally, the challenges of learning during the pandemic, the limitations on the students, the interest in motivating and interesting them, and the development of educational resources to overcome deficiencies are all recognized.

Table 2
Overview of active learning experiences in the MIT SCALE LATAM

Initiative	Subject(s) Period(s)	University	No. professors	No. students	Objective	Skills	Student assessment
Social Lab for Sustainable Logistics	Systems Dynamics (January-May 2020, August-December 2020 and January-June 2021)	Tecnológico de Monterrey (Mexico City)	1	75	Model and study complex projects using system dynamics tools applied to real logistics and supply chain situations in sustainable cities and communities during the pandemic, with a focus on food security	The ability to apply engineering design to devise solutions that meet specific needs, taking into account public health, safety, and wellbeing as well as global, cultural, social, environmental, and economic factors.	Final project and exams
Learning applied to virtual challenges	Integrated Logistics (I/2020)	Universidad Privada Boliviana (Cochabamba)	1	25	Study and propose improvements to warehouse and distribution processes at a beverage company	Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	Presentation of challenge
Learning applied to virtual challenges	Integrated Logistics (II/2020)	Universidad Privada Boliviana (Cochabamba)	1	11	Study and propose improvements for complex systems in a context of sustainable communities	The ability to apply engineering design to devise solutions that meet specific needs, taking into account public health, safety, and wellbeing as well as global, cultural, social, environmental, and economic factors.	Presentation of challenge

Collaborative International Learning	Integrated Logistics (II/2020)	Universidad Privada Boliviana (Cochabamba)	2	11 UPB students and 24 Universidad de la Sabana students = total 35	Design and model the location and distribution of key foods for the regions of Bogotá and Cochabamba.	The ability to apply engineering design to devise solutions that meet specific needs, taking into account public health, safety, and wellbeing as well as global, cultural, social, environmental, and economic factors.	Final project
Learning applied to virtual challenges	Value Engineering Management (I/2020)	Universidad del Pacífico	1	30 per period	Integrate concepts to promote understanding of the impact of decisions in each functional area of a company and throughout the supply chain	The ability to integrate the knowledge acquired during the course, effectively communicate the results of the projects, and work satisfactorily with the work team.	Proposal based on simulation

4. Education beyond the pandemic

Universities in the MIT SCALE LAC network have developed initiatives for teaching Industrial Engineering based on a new conceptualization of remote learning experiences in response to the educational challenges that have arisen during the COVID-19 pandemic. As Table 2 shows, each university has carried out activities under the remote modality based on its own capacities and limitations. Although some activities were restricted and had to be adapted—such as those linked to challenge-based learning—other opportunities arose, including a collaborative learning experience between two universities in the region. The professors' learning experiences in the different situations they faced must be deployed in the post-pandemic environment. It is worth highlighting the universities' flexibility and resilience, which ensured academic continuity during the pandemic through learning experiences to actively develop skills and relevant practical activities centered on contemporary issues in the discipline. However, the pandemic still poses challenges for the new educational reality, which will continue transforming teaching and learning in the future.

The disruption caused by the COVID-19 pandemic raised concerns about a lack of socialization and the academic contribution of universities in remote learning amid public health restrictions and social distancing measures. During the pandemic, new models and formats of remote, blended, or online learning emerged along with novel educational technologies for autonomous work and remote communication and interaction. However, students also had to develop new types of active learning activities and new skills in order to perform effectively in the recently introduced remote environments. When interactions and communication change, new understandings, requirements, and expectations about teaching and learning emerge, which has also created new needs among students that universities must meet.

It is now common to find a growing supply of remote or online courses and programs due to the persistence of the pandemic but also because of a preference for distance study at the undergraduate and graduate levels. Massive open online course (MOOC) platforms such as EDX, Coursera, and those provided directly by universities in association with companies specializing in online content management are redefining the global educational offer (Ramírez Montoya, Romero Rodríguez, & Castillo Abdul, 2021). This situation has opened up extensive and accessible national and international educational offering that calls into question the relevance of face-to-face education and forces universities to enrich the value that they deliver to their students locally.

In this regard, higher education, and, in turn, Industrial Engineering and its related fields, must consolidate an educational proposal focused on collaboration, social interaction, and the relevance of learning, as well as reinforcing student motivation and interest, the development of relevant skills, and the provision of active experiences within in-person and remote, synchronous, or asynchronous formats. Universities must reinforce the various aspects of their teaching efforts to redefine a proposal for high-value learning experiences. To this end, Figure 1 presents a concept map to guide design and reflection on learning experiences during and after the pandemic. It is based on the ideas discussed in this study, which have elucidated the importance of addressing the educational requirements of the various stakeholders; the educational trends and challenges faced by different societies when it comes to assuring the relevance of education; and universities' value proposals and educational services, pedagogical approaches, educational resources and technologies, and assessment of learning and its impact.

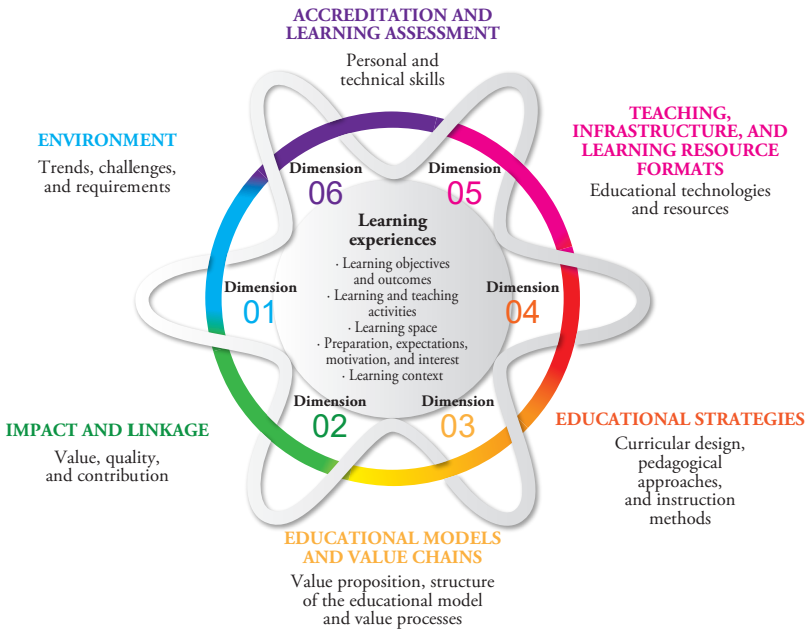
This scheme has also been developed taking into account prior experiences reported in Salinas-Navarro, Garay-Rondero and Calvo (2020), and through a bibliographic review of educational innovation in higher education, which point to different visions and understandings of innovation and educational leadership. These studies refer, in an isolated or individual way, to perspectives that need to be incorporated into an integrative scheme that complements the different areas of focus (see Everhart & Doyle, 1980; Jacob, 1997; Larrivee, 2000; Silva & Sheppard, 2001; Vera et al., 2006; Spiers & Hervey, 2011; Kromydas, 2017; Serdyukov, 2017; Mynbayeva, Sadvakassova, & Akshalova, 2017; Halasz, 2018; and McCune et al., 2021). A similar example of integration can be found in the Tecnológico de Monterrey (2017) report titled *Radar de innovación educativa*. However, that report only characterizes and maps existing pedagogical approaches, instructional innovations, and educational technologies.

The learning experiences, a central part of the scheme, are the result of a convergence of different strategies, structures, processes, and resources that are recreated in teaching and learning activities in specific educational spaces and contexts (Salinas-Navarro, Garay-Rondero, & Calvo, 2020). Learning experiences correspond to specific requirements and objectives for each educational program and its courses. Students participate, interact, and communicate in their learning experiences based on their perceptions, understanding, and expectations, as well as their own preparation, personal circumstances, motivation, and interest.

During the pandemic, the incorporation of students—and their professors—under exceptional social distancing and health emergency

conditions was key to providing continuity to remote learning experiences (Usher et al., 2021). This involved taking into account their physical and mental health, as well as the characteristics of the physical environment and access to available technological and learning resources to carry out their activities. It then becomes incumbent to ensure adequate student inclusion, interaction, and collaboration in their learning spaces under the prevailing circumstances (Salinas-Navarro, Mejía-Argueta, Da Silva-Ovando, & Garay-Rondero, 2020). The instructional design of experiences can determine the details of learning activities and resources according to six dimensions, which draw from the authors' experiences during the pandemic to conceptualize and design future learning experiences for in-person, remote, and blended environments. An example of this is the ADDIE method (analyze, design, develop, implement, and evaluate) (Branch, 2009).

Figure 1
Outline of factors for inclusion in the design of learning experiences



Source: Compiled by authors.

To achieve this, learning experiences can be designed from a multidimensional and complementary perspective of educational innovation and leadership that encompasses:

- **Dimension 1**: Future trends, challenges, and external educational requirements to which universities must respond in their activities
- **Dimension 2**: The impact to be achieved through community engagement and the value and quality of the contributions made
- **Dimension 3**: Educational models based on value creation processes for different audiences
- **Dimension 4**: The use of active, practice-oriented, student-centered, and collaborative pedagogical approaches and instructional methods
- **Dimension 5**: The availability of an educational infrastructure consistent with the pedagogical approaches, and the use of interactive and online educational resources
- **Dimension 6**: Educational quality assurance and the fulfillment of learning objectives through processes of institutional accreditation and assessment of the development of personal and disciplinary competences

By applying these dimensions, learning experiences are expected to be relevant, motivating, and of interest to students, leading to an improvement in their current learning and future professional prospects (Salinas-Navarro, Mejía-Argueta, Da Silva-Ovando, & Garay-Rondero, 2020). There is also a need to assure a contribution to educational quality, to the positioning of educational institutions, and to benefit to communities and society. The requirements established by national or international accrediting entities such as ABET (https://www.abet.org/), PRME (https://www.unprme.org/), the World Economic Forum (WEF) and the Organization for Economic Co-operation and Development (OECD) must also be met. This vision complements and integrates educational strategies and teaching and learning activities that are traditionally isolated or fragmented. The present study therefore proposes the concept map in Figure 1 as a tool to enrich the practice of education, and specifically education in Industrial Engineering, by conceptualizing, designing and incorporating far-reaching experiential activities, learning challenges, and active teaching projects or problems into courses and programs. The map also locates and positions educational initiatives within the spectrum of the six dimensions proposed and reflects on their coverage and scope.

5. Conclusions

This article, which explores the experiences of Industrial Engineering undergraduate programs at three private universities in the MIT SCALE LAC network, provides insight into how Latin American higher education institutions faced and responded to the COVID-19 emergency, and how academic

activities continued with relative normality despite the global uncertainty unleashed in March 2020. The challenge began from the moment that the different governments declared their confinement measures, which required educational centers to devise agile and flexible strategies to ensure that students enjoyed the same quality of education as they did through in-person learning. In developing countries with an incipient digitization infrastructure, these responses have exhibited great limitations but also great opportunities to improve and diversify future learning experiences in the post-pandemic period.

Taking this context into account, this study drew on the authors' experiences during the pandemic to classify six dimensions and conceptualize and design future learning experiences for in-person, remote, and blended environments. Given the considerable investments made by universities over the last two years to deal with the crisis, it is clear that institutional efforts and strategies should be directed at maximizing both physical resources and learning experiences acquired. This will also contribute to the fulfillment of learning objectives and the development of students' skills, assuring educational quality and the relevance of learning.

At the same time, these dimensions define conditions and requirements that shape learning experiences by incorporating the universities' environmental and strategic aspects, linkage, accreditations, educational models, and teaching approaches and resources. All this is brought together in the recreation of learning experiences, whereby professors and students interact in the specific spaces, contexts, and situations in which they engage in their activities, confront challenges, and exhibit their personal characteristics. Professors become facilitators for students in the process of learning skills and creating value in both in-person and remote environments.

It should be noted that the examples presented here refer to academic programs that include courses related to logistics and supply chains, so the active experiences in question revolve around these topics. Moreover, the universities included in the sample are private institutions that possessed the educational resources with which to support adaptation during the pandemic. Likewise, these institutions have explicit definitions regarding their accreditation processes, academic quality, community relations, and use of educational strategies and teaching approaches oriented towards leadership and educational innovation. Thus, the present work should be extended to explore the experiences of other disciplines and public institutions so as to ascertain and analyze their efforts and achievements and disseminate them among the wider community.

Following on from this study, it is suggested that a research agenda on educational innovation and leadership be developed in order to guide the

educational efforts of the discipline of logistics and supply chains, while also serving as a reference for other areas of knowledge and teaching. This future agenda could: (i) establish a method for the development of learning experiences in accordance with the proposed concept map; (ii) extend the design and application of learning experiences; (iii) validate their effectiveness and impact for the different beneficiaries, especially in terms of student learning and skills development; and (iv) inform future work on the dimensions of the proposed map in order to reflect on its scope and limitations.

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