Scale up Process: An educational immersion model in the industry

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Abstract*– University education for innovation has become a global strategic measure to develop scientific and technological progress. Traditional universities are based on this model where great importance is given to the transmission of culture and knowledge, since they are believed useful to help the student to form a disciplined personality. This position dominates contemporary university education, it is a theoretical model where students do not have much interaction with real models that will be useful in their incorporation into the production chain and industry. New models to ensure the students to develop skills to succeed in a highly competitive world. This project aimed to represent an educational immersion model of a scale up factory-type chemical process. This project intended to make students put their knowledge into a real collaborative environment by the production of two skin care products from a real company. During the development of the project, 51 students were exposed to a process scaling experience in real manufacturing conditions for the production of cosmetic products for the personal care industry. This project represents an example of an innovative educational model in the University since it allows students to develop entrepreneurial skills through an experience on a real industrial production with an impact on their professional development.

Keywords—Scale up process, educational immersion model, innovation, entrepreneurship, higher education.

I. INTRODUCTION

Scale-up analysis is a vital tool to expose the university student to an immersive experience of what an industrial process is. Scale-up process is one of the most important tasks both during plant design and during normal operation [1]. During their immersion in the production plant, students can reduce or correct errors in direct designs due to inexact correlations or lack of information.

On the other hand, students can develop a real-scale experience, increase the "know how", which in a global way allows them to have the experience of generating knowledge to support future decision-making in new or existing process plants [2]. Pilot plants in the chemical industry are a fundamental element both in the training of engineers in Good Manufacturing Practices and in the scaling up of equipment decision making, since they can experience the factors involved in these aspects. In addition, these experiences allow students to carry out more assertive economic analyzes to develop future project proposals.

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In this work, the results of the development projects for the scale-up of chemical factory-type processes are presented, as an example of the teaching-learning models related to the immersion of students in the industry.

A. Traditional Education

The development of online education, informational society, industry 4.0, and the widespread diffusion of information technology gives rise to new opportunities for learning and they challenge established views and practices regarding how teaching and learning should be organized and carried out [3].

Especially, with the rise of Industry 4.0, engineering education has undergone a significant renewal in the last two decades. However, undergraduate students sometimes lack industry exposure and cannot visualize the complexity of processing plants and how they evolve from laboratory to industrial production. Therefore, they are likely to be able to graduate without adequate professional practical experience.

It is well known that traditional classes taught at all educational levels remain, essentially, without fundamental changes following a sequence: presentation of the contents by the teacher, and the implementation of these contents in a very theoretical way [4].

The latter, based on the resolution of exercises or through the preparation of written work with oral presentation. It should be noted that, in a traditional class, focused on the transmission of knowledge by the teacher, the students' ability to concentrate and capture information decreases after about an hour. Likewise, interaction is very low, which makes it difficult for students to question, while the expected passivity of the rest of the classroom reduces interest and the ability to learn group knowledge [5].

B. The transformation of education

Higher education is facing the challenge of create and distribute socially relevant knowledge and it is part of their responsibility to do so while adhering to interactive learning models that allow students to easily join the production chain and play a proactive and committed role in the transformation and changing societies and industry.

In recent years, there has been a growing interest in transforming undergraduate engineering education towards a more active approach and according to the needs of the industry [6]. Complex market demands combined with the technological evolution of products and processes lead to the need for engineers who are capable of reacting and evolving, taking advantage of the flexibility, capacity to change and scalability to remain competitive in dynamic production contexts [7].

To successfully answer these challenges and new forms of life, universities must transform themselves by adopting a lifelong learning system and many strategies.

This system will transform how universities currently teach.

To achieve this transformation, universities will have to introduce strategies and policies which implement flexible academic frameworks, innovative pedagogical approaches, new forms of assessments, and institutional collaboration.

Some of the key recommendations to achieve the above are:

- Motivate learning by connecting the subject of the course with previous experiences and learning, as well as with future applications.
- Allow students the opportunity to work as a team and learn from each other.
- Provide open problems and the closest to reality that allow analysis and synthesis.

All this as a formal commitment of the universities in the promotion of inclusive business and industrial ecosystems that encourage equitable growth in the student through entrepreneurship [8]. Therefore, this innovation aims to confront a group of students with real environments for scaling processes through an integrative project in the class of cosmetic formulations with the development of two skin care products from a real socio-training company as a model for the generation of knowledge and in order to encourage students to make future decisions in chemical processing plants.

II. Innovation Description

A. Cosmetic formulation course

The cosmetic formulations course is an optional credit topic at Tecnologico de Monterrey that engineer students can choose as a part of their curricula. The objective of this course is to teach students a general training base regarding the elaboration of a chemical processes and the production of cosmetic formulations. The students work in in teams and it is expected that by the end of the course they will be able to develop their own formulations, as well as be able to carry out their process control analysis. In its traditional form, the final exam is the elaboration of a cosmetic product for the skin selected by the teacher and elaborated on a laboratory scale (400 g) by each team.

This final project, although it develops the cognitive knowledge, it does not allow the student to glimpse the processes on a real scale in the industry. In the immersion model proposed in this innovation, a training partner company in the skin care sector provides the project to be developed with a formulation of its own catalog and the students are in charge in its production in a scale-up process of up to 14 kilograms per product in question.

By carrying out the production in a real industry environment, the students of engineering at Tec de Monterrey experience real-life learning challenges, allowing them to collaboratively develop new skills such as creativity, problem solving, entrepreneurship all through solving real problems on an industrial scale process.

B. Innovation implementation

Throughout the last year, the cosmetic formulation course has had 51 students of 5 different careers of engineering areas (Figure 1). The collaborative teams were composed by students of different areas to encourage the multi-disciplinary experience in the students.

Each team produced two (2) skin-care products, a hair removal retardant depilatory cream, which had medium viscosity and light texture with a retarding effect on the body hair.

On the other hand, the stretchmarks cream was a highly emollient cream, specially designed to prevent the appearance of prenatal stretchmarks and help postnatal stretchmarks to disappear.

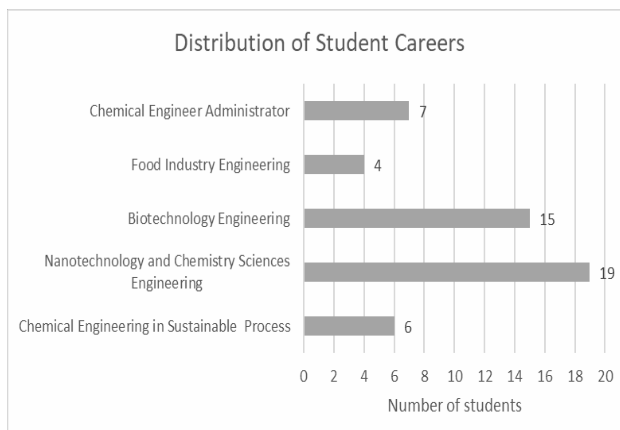

Fig. 1 Engineering areas of students that participated in the Cosmetic Formulation Course.

The total production for the depilatory cream was 28 kg divided in 2 batches of 14 kg each, while the stretchmark cream had a total of 36 kg produced in 3 batches.

This configuration allowed the students to oversee different production areas and develop a variety of activities (Table I). The collaborative activities where design to allow each team to be responsible of the different production areas. On the other hand, individual roles refer to individual activities of each student within each group.

C. Evaluation outputs

At the end of each production, each team submitted a technical report that includes different process parameters.

An open kettle type reactor of 18 kg capacity with digital temperature control and stirring was used (Intertecnica MEV-80, De Volteo Industrial) (Figure 2).

This reactor, being an open system, requires an adjustment of 8 to 10% in the added water, which is lost by evaporation during production. So, each team must make the calculations required to make the adjustment in the production due to the evaporation of the open system.

The successful scale up process is considerably dependant on the evaporation as means for controlling the process variables along through the whole process [9]. Thus, apparent downsides could be avoided that might cause variability and quality concerns in the final product.

TABLE I
ACTIVITIES OVERSEES BY EACH TEAM DURING THE SCALE-UP PROCESS

Activity	Type
Equipment cleaning and sanitizing	Collaborative
Material weight and calculations	Individual roles
Reactor programming	Individual roles
Production	Collaborative
Process control	Individual roles
Reactor emptying	Individual roles
Quality controls	Collaborative
Packing and labelling	Collaborative

An elemental portion of engineering education is practical learning and experience of methods, equations, principles and procedures for the development of real cosmetic products.

The production of cosmetic products are varied and generally have low technological complexity.

Most processes are characterized by the physical mixing of the various raw materials and assembly, rather than the creation of chemical reactions.

However, the control of certain parameters in production directly affects the quality of the final products.

By these means, the process variables analyzed where temperature control, cooling temperature gradient, pH and neutralization, and the final product viscosity.

Fig. 2 Open kettle type reactor of 18 kg capacity with digital temperature control and stirring (Intertecnica MEV-80, De Volteo Industrial).

These variables are essential parameters for quality control in the application and in all manufacturing procedures [10].

The technical report was evaluated according to a systematic rubric that allowed the professors to evaluate the work done and give punctual feedback to each team (Table II). Areas such as product awareness, materials and equipment knowledge, "know-how" understanding, quality controls checkup, and analysis of the information were evaluated. This element of evaluation could assist in understanding the perception of student from producing a cosmetic in a traditional way compared to an actual industrial environment.

TABLE II
TECHNICAL REPORT RUBRIC OF THE SCALE-UP PROCESS

Content	Value
Product description (introduction)	10
Materials description, batch size, formulation, and final product composition	10
Process diagram	10
Process observations	15
Process control parameters	30
Conclusions	10
Process graphic analysis	10
Individual experience comments	5

III. RESULTS

One of the most important points during the scaling process was the follow-up of all the production control parameters. As a contrast of engineering educators using the traditional approaches, the students gain complete knowledge of product manufacturing, hard and soft skills and gain more confidence over real-world projects. In this particular experience, the most important parameters that students were monitoring during production processes were:

- The pH which must be kept above 3 during production and adjusted at the end between 6.2 and 6.8.
- The viscosity which adjusts in the end to the centipoises marked by the standard.
- The temperature which is an essential parameter for the quality of the final product. The temperature must be kept below 80 degrees centigrade during production and below 40 degrees centigrade to add the active ingredients, the volatile components and the fragrance of the product.

The recognition of the differences that these parameters can have when they are carried out on a laboratory scale against those carried out on a pilot and industrial scale. Figures 3 and 4 show the weighing and temperature control activities during the scaling process. The industrial equipment possessed digital control parameters that allow the students to reduce the variability within the experiments. The accuracy of the formula ingredients weighting and processing allows to set the models for sensorial perception and desired product properties expected by consumers [11]. Furthermore, the systematic control of the process variables grants that every product matches the regulatory and safety framework that the law stablishes and thus avoids any fine [12]. By these means, the students could gain insights in relevant topics indirectly related with production such as marketing and legal regulations.

Fig. 3 Weighing of materials during production

A. Class with traditional class vs process scale-up model

The main objectives in the implementation of this innovation were to i) be able to compare if the scaling had an impact on the evaluations and to ii) determine the development of the soft skills of the students.

To do so, we compare the students who took the course with a traditional evaluation and those with the final evaluation of the escalation. As an instrument of the student development, we consider at first the final grades, where 4 groups of students were compared.

The Group 1 (12 students) and 2 (13 students) had a traditional evaluation, in which their final project was performed at a laboratory scale. On the other hand, Group 3 (20 students) and Group 4 (15 students) had the innovating scaling experience. Despite all students obtained over 90 points, significant differences were observed among both type of experiences (Figure 5 and Table III).

There is clear increment in the final grades in the scale up model due to the awareness of the students and the understanding that each production area had an impact on the final product quality.

This may initially indicate that the scaling experience improves student learning process by interiorizing the theory. For example, this experience allowed students to learn about risk and process safety.

Tiempo (minutos)	Temperatura (°C)	
5	28.8	Calentamiento
10	39.4	
15	61.4	
20	70.1	
25	71.8	
30	63.4	Enfriamiento
35	62	
40	58.8	
45	56.6	
50	52.3	
55	50.6	
60	49.5	

Fig. 4 Production process control. Recording of temperature gradient in the industrial scaling of the process.

A previous study in industrial engineering educational model revealed that these experiences change how students think, and had a positive perceptions towards developing professional engineering competencies [13].

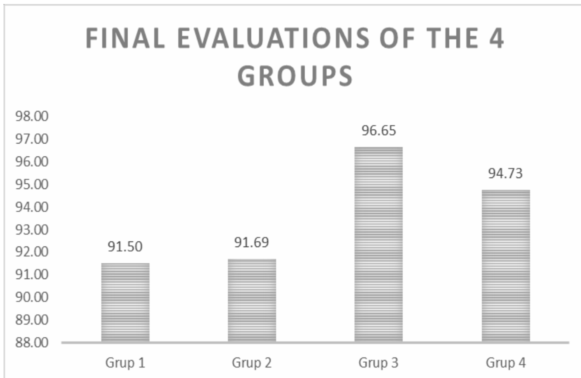

Fig. 4 Final evaluations of the 4 groups

TABLE III
FINAL MEANS AND STANDARD DEVIATIONS OF THE GROUPS COMPARED

	Grup 1	Grup 2	Grup 3	Grup 4
Average	91.50	91.69	96.65	94.73
Standard deviation	1.31	1.84	1.05	1.71

As stated in the opening paragraphs, current higher education implies a change from teaching to learning. This education requires students to assume an active role, in addition to the development of autonomy and learning capacity.

In this context, courses must be designed specifying the learning outcomes that students are expected to obtain, expressed in terms of different types of competencies that are developed throughout the process [14].

A point of utmost importance is that students develop the ability to work in a team and know how to adapt to their diversity. In this sense, in all the groups where the scale-up production project was implemented as a final evaluation.

The active and responsible participation of the teams was achieved, as well as the monitoring of roles during the execution of the assigned projects. This role experience increases the ability of students to understand the whole picture of what´s going on the production line [15]. Furthermore, industrial experience increases students' recognition of documentation and that it needs to occur throughout the process.

By these means, this experience strengthen the of soft skills of teamwork, planning and management of production time in the students of all professional careers who participated in the scale up project for the production of cosmetic creams.

Finally, tthroughout a survey of students' perspectives we were able to determine the efficacy of these efforts. This tool have been an effective tool to obtain the perception of engineering students towards professional skills that had an impact on their employability [16].

Regarding the final opinion of our students, Table IV shows some comments from the students of the project. By the scale-up model we could find that students experienced a different way of learning that allowed them to notice the relevance of controlling the process variables, had an efficient communication inside the teams and outside towards other departments related to production.

IV. CONCLUSION

The industrial scale-up of a production process for two skin care products was carried out as a final project for the Cosmetic Formulations Course.

The students who were participating in this educational experience tended to obtain better final evaluations than those who took the course in a traditional way.

The soft skills of teamwork, planning and production time management in the students of all the professional careers that participated in the cosmetic cream production escalation project were developed satisfactorily.

This project represents an innovative learning model that allows students to have an enriching immersion experience showing them what it is like in the industry.

The development of immersive environments in our students is of the utmost importance in their future performance in the corporate world [4].

This type of immersion project in a real environment offers us a viable alternative as a higher education institution, to motivate students to change their way of learning and thus encouraging them to participate more actively in their learning process.

It also allows to visualize the complexity of real product processing plants in the skin care area.

As future works, it is intended to carry out the implementation of the scaling process in heterogeneous scaling processes that allow the student to be exposed to other common unit operations in the chemical industry.

TABLE IV
FINAL COMMENTS FROM STUDENTS REGARDING THE FINAL EXAM WITH THE PROCESS ESCALATION PROCESS.

Student	Comment
Ana Sofia T.	I found the scaling process of the cream gel very interesting, the use of the reactor left me with a lot of learning. It is very different to make a product in a small presentation where if you need to cool it, you put it in a bain-marie and stir, to when you need to cool a pot with 14 kg of product, where you have to cool it with a hose. I thought it was an excellent experience to have assembled the product for a real company on an industrial scale.
Isabela B.	Carrying out an industrial scale-up was a new challenge for

	the team. The difference between the products that were made in class on a small scale and the scaling epilatory cream was very noticeable both in the time spent in production and the control parameters.
Elizabeth H.	I found it very interesting to elaborate the formulation on an industrial scale as we did in the final practice, since we were able to observe how real companies operate and the parameters that we must take into account from the calculations, the formulation, the packaging and the labeling.
Gabriel N.	The final evaluation with the scaling was very useful, it was definitely a challenge to use a facility that I was not used to, however, it was an enriching experience to learn how to scale a process.

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