

# Emergency remote teaching in process simulation using DWSIM: a case study from DIQ-UMAG, Chilean Patagonia

Enseñanza remota de emergencia en simulación de procesos con DWSIM: un caso estudio DIQ-UMAG, Patagonia Chilena

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Artículo de investigación científica y tecnológica

**Abstract**— Due to this worldwide COVID-19 pandemic, Chilean universities were forced to quickly change their face-to-face classes to online. In this context, the Department of Chemical Engineering (DIQ) of the University of Magallanes, Chile, seeks different Emergency Remote Teaching strategies for its students. This article reports they experience delivering technical process simulation skills to their final year undergraduate civil engineering chemical engineering students. Due to problems connecting externally with the commercial software Aspen HYSYS, housed at the university, the open source software DWSIM is taught as an alternative. The material content was adapted, and video tutorials were created to meet learning objectives. This software was taught in a new module inside the Project Engineering course to train the skills required for the students to design and simulate a chemical plant. We received positive feedback and constructive critics from the students through an anonymous survey and discussion forum. Subsequently, DIQ launched its YouTube channel named DIQ\_DWSIM with the videos made to the online community, positively impacting Spanish-speaking people who wish to learn to use DWSIM. As an indirect impact, two universities have used this channel as support material in their process simulation courses. A second survey was conducted on our YouTube audience resulting in the consolidation this open online educational resource for higher education learning.

**Index Terms**—DWSIM, process simulation, COVID-19, remote emergency teaching, YouTube channel.

**Resumen**—A causa de la pandemia COVID-19 en el mundo, las universidades Chilenas se vieron obligadas a cambiar sus clases presenciales a modalidad online en poco tiempo. En este contexto, el Departamento de Ingeniería Química (DIQ) de la Universidad de Magallanes, Chile, busca diferentes estrategias hacia una Enseñanza Remota de Emergencia para sus estudiantes. Este artículo reporta su experiencia en entregar las competencias técnicas de simulación de procesos a sus estudiantes de último de año de la carrera de pregrado ingeniería civil química. Debido a problemas para conectarse externamente con el software comercial Aspen HYSYS, alojado en la universidad, se enseña como alternativa el software de código abierto DWSIM. Se adaptaron las tutorías y se crearon videotutoriales para cumplir

con los objetivos de aprendizaje establecidos. Este software se enseñó en un nuevo módulo dentro del curso de Ingeniería de Proyectos para entrenar a los estudiantes con las habilidades necesarias para diseñar y simular una planta química. Se recibió retroalimentación positiva y críticas constructivas de parte de los estudiantes a través de un foro de discusión y encuesta anónima. Posteriormente, el DIQ lanza su canal de YouTube DIQ\_DWSIM con los videos realizados a la comunidad online, logrando un impacto positivo en personas de habla Español que deseen aprender utilizar DWSIM. Como impacto indirecto, dos universidades nos contactaron para utilizar nuestro canal como material de apoyo en sus cursos de simulación de procesos. Se realizó una segunda encuesta con nuestra audiencia de YouTube, resultando en la consolidación de este recurso educativo abierto online para el aprendizaje en educación superior.

**Palabras claves**— Canal YouTube, DWSIM, COVID-19, Enseñanza remota de emergencia, simulación de procesos.

## I. INTRODUCTION

Educational institutions around the world have had to forcibly migrate from face-to-face or semi-face-to-face teaching to a complimentary online modality due to the COVID-19 pandemic in a short time. This transition has been challenging for the institutions and staff in public Latin American universities. The required technical and digital skills in teachers, together with institutional support, may be deficient. In addition, the internet connection speed and the availability of needed electronic devices [1].

The term that best describes teachers' rapid and unplanned migration is Emergency Remote Teaching (ERT), which has emerged as a definition coined by education experts to differentiate between assisted education and the immediate response towards an emergency education. A high-quality virtual education course at the university level requires 6 to 8 months of preparation. In contrast, the ERT is a response in which there is an initiation time of no more than one week, and in which adjustments are made on the fly as the content of the subjects progresses [2].

This paper reports the case study of the Emergency Remote Teaching methodology implemented to acquire the technical

skills of process simulation within the Project Engineering course. This course was conducted in the first academic semester of 2020 for the final year undergraduate degree students in Chemical Civil Engineering, Department of Chemical Engineering of the University of Magallanes (UMAG), Chile. The context, the teaching of the simulation of processes before the COVID-19 pandemic in the academic unit, the justification for selecting DWSIM as alternative software, the methodology applied to create a DWSIM module, and the development of video tutorials are described. The results obtained from an anonymous survey and discussion forum carried out with the students are reported; also, the impact of the launch of our YouTube channel DIQ\_DWSIM in the online community is outlined.

#### A. Use and importance of teaching process simulators in chemical engineering

Currently, the higher education institutions that teach chemical engineering programs use different tools in their teaching. These generate added value to the training of students and the acquisition of key technical skills to be appropriately inserted in the workplace. The use of process simulators is an example of this, as an indispensable tool in the training of chemical engineers due to their ability to reinforce the knowledge students acquire during their study programs [3].

According to Haydary [4]: *“in a complex problem, the solution of many thousands of equations is often required. Therefore, hand calculation of such problems in real time is practically impossible and process simulators are an irreplaceable tool”*.

Therefore, modern teaching cannot be conceived without the use of a computer. Computers allow the resolution of complex calculations with speed and reliability in engineering so that companies dedicated to engineering design (e.g., aeronautical, automotive, chemical-industrial) have adopted programs computer-aided for their daily work and simulation design [5].

The learning process of simulation software requires an understanding of what is happening in it and how it uses different methods to solve chemical engineering problems. Learning for yourself how to use software simulation may not be the right fit. Therefore, it is essential how teachers train and present the tools and computational criteria used to interpret the results [6].

Therefore, process simulation is one of the primary technical knowledge in the training of a chemical engineer. Through simulator-based learning, teachers use commercial software to simulate industrial chemical processes and thus reinforce the theoretical background of students, e.g., [7].

#### B. Educational local context with the COVID-19 pandemic

The Department of Chemical Engineering - from now on DIQ - is geographically located in Punta Arenas city, capital of the Magallanes and Chilean Antarctic Region, part of the Chilean Patagonia. The regional population is approximately 166,553 people [8], representing around 0.95% of the Chilean population. UMAG is the only state university in the region that offers 22 professional and 22 technical majors, with an average

enrollment of 3,700 students. DIQ offers undergraduate programs in Chemical and Environmental Engineering and Chemical Civil Engineering, with a total average of 84 students, where, on average, 5 students per career graduate annually [9]. It is important to mention that we are located in an extreme area, with a geographical connection by land only through the Argentine territory or by sea through ferries or, flying by air. This condition makes connectivity limited, making communication with other regions precarious and delaying the arrival of cutting-edge technology to improve the internet connection [10].

On the other hand, the Chilean state universities in the last period have been affected by different student protests, causing them to reduce their teaching hours to finish the academic year. The UMAG is not immune to this, so, year after year, teachers and students have to plan how to complete their respective courses to meet the learning objectives. The year 2019 was affected by the student strike [11], affecting the end of the second academic semester on April 30, 2020, and starting the 2020 academic year on May 4, 2020, two months later than usual [12].

On March 3, 2020, the first case of contagion by COVID-19 [13] was confirmed, and, on March 18, 2020, Chilean President Sebastián Piñera decreed the country to be in a state of catastrophe for 90 days, subsequently intermittently extended until the submission of this work [14] [15] [16]. On March 16, 2020, the UMAG notified the student community that classes were starting online [17]. Then, on April 1, 2020, the city of Punta Arenas began the first of four quarantines due to being one of the cities with the highest contagion rate in the country [18].

#### C. Process simulation in the DIQ in pre-COVID-19 times

Navarro-Pérez and Llerena-Chávez [19] explain how process simulation is taught in the DIQ's chemical civil engineering program (see Fig. 1). In semester X (fifth year), the teaching of chemical process simulation begins in Computational Process Simulation. This course is divided into two central units: programming in Microsoft Excel using the Visual Basic for Application (VBA) language and the Aspen HYSYS process simulator. In both units, chemical processes are modeled and simulated based on a real context.

Aspen HYSYS is a process simulation software used by the vast majority of industries related to energy, oil and gas, refineries, and engineering companies to optimize processes and operations design [20].

Simulation-based learning is used to teach this software through face-to-face tutorials guided by the teacher. One of the learning objectives is to use Aspen HYSYS to apply the theoretical knowledge acquired in previous years on unit

operations. Students reach an intermediate user level at the end of the course, simulating simplified chemical plants in a steady state. This knowledge becomes relevant in semester XI (sixth year) when students take the Project Engineering course. In this course, each student assumes a role as a project engineer, where they have to design a chemical plant or part of a chemical process, applying everything they have learned in the curricular program. Through progress reports, they carry out three stages where the software is used as a tool: i) in the preliminary study, an outline of the plant to define the process flow diagram or flowsheet; ii) in preliminary basic engineering, they fine-tune both the modeling and the simulation of the chemical plant, this includes the sizing of the equipment involved; iii) in the pre-feasibility study, they simulate different plant production scenarios to find the bottleneck points, and thus define the operating limits in each piece of equipment.

#### D. Problems in teaching process simulation and justification for selecting DWSIM

The academic year 2019 ended in online mode. Both teachers and students could not connect to the Faculty of Engineering domain remotely, and so obtaining access to the DIQ server and using Aspen HYSYS. This eventuality caused that in the Computational Process Simulation course, it was not possible to teach this software to the students of semester X. The reasons that caused this problem are shown in Table I, where the main problem is the remote connection. In the beginning, a return was predicted (face-to-face teaching), so it was expected to resume this unit in semester XI. However, with the arrival of the pandemic in Chile, intermittent quarantines began in our city.

Due to the above, an Emergency Remote Teaching methodology had to be established, beginning the search for alternative software to Aspen HYSYS. The teachers in charge of the Computational Simulation of Processes and Project Engineering courses analyzed different software from the perspective of open-source license and complementary material availability to learn how to use it as a user. Through searching the Internet and consulting with colleagues in the discipline, we found two process simulators as potential alternatives: COCO [21] and DWSIM[22].

Table II shows the analysis conducted, comparing, by different categories, what each software offers compared to Aspen HYSYS. Contrasting the alternatives from the point of view of language, license, installation, and customer service, both are similar and comparable. While the difference is in the simulation modes and the complementary material available. COCO only simulates in a steady state, while DWSIM also includes the dynamic state. The latter is crucial because, within the training of the chemical engineer, the instrumentation and control of processes can be simulated, something that Aspen HYSYS offers. COCO offers presentations, reference articles, sample files, and help regarding the learning resources available to use the software on its official pages. DWSIM provides all of the above, plus online courses and teaching videos. This category made the difference in our final decision to use DWSIM as an alternative software.

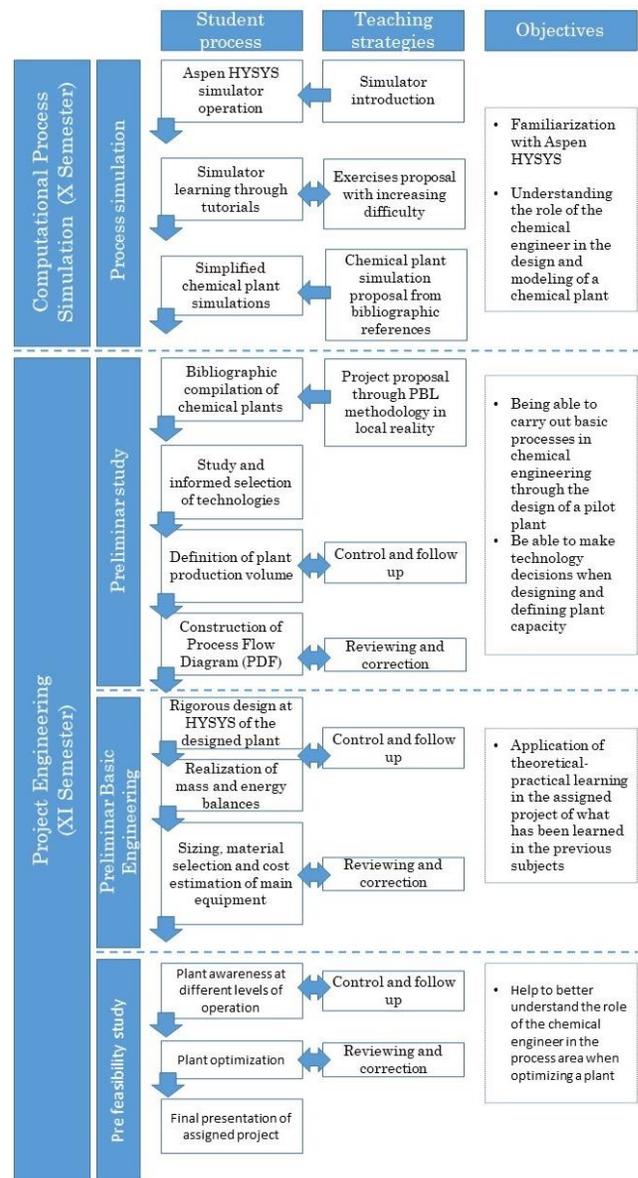


Fig. 1. Summary diagram of the process simulation teaching methodology at DIQ-UMAG modified from [19].

TABLE I  
CLASS TYPE COMPARISON FOR TEACHING ASPEN HYSYS AT THE DIQ

| Category                     | Face-to-face class   | Online class   |
|------------------------------|--|--|
| <i>Software installation</i> | It is unnecessary for the students to install the software on their work equipment since the AspenONE software is installed on a DIQ server and can be used from any computer connected to the server.               | Students must install the software on their work computer, which means that students cannot meet the minimum installation requirements.  |
| <i>License access</i>        | Access to the software license is obtained through the local network of the Faculty of Engineering of the UMAG. Specifically, the educational license is of the server type (License Server) stored on a DIQ server. | Access to the software license is not established in online mode. The only option is to connect to the DIQ server by VPN (Virtual Private Network or Virtual Private Network). |
| <i>Connection type</i>       | The software is configured to work through the university's domain (local network).  | A remote connection is required to access the software, which is not feasible due to the instability of the Internet connection in the region.                                 |

TABLE II  
COMPARISON OF COCO, DWSIM AND ASPEN HYSYS COMMERCIAL SIMULATORS.

| Category                                  | COCO [21]  | DWSIM [22]  | Aspen HYSYS [20]   |
|---|--|---|--|
| <i>Language</i>                           | English  | English and Portuguese  | English  |
| <i>License Operating systems</i>          | Open-source Windows  | Open-source Windows, macOS, Linux, and iOS  | Private (Paid) Windows   |
| <i>Customer support</i>                   | Does not provide direct support only discussion forums.  | Does not provide direct support unless the user is a sponsor. It also has discussion forums.  | It has online customer support, complementary material and discussion forums.  |
| <i>Simulation modes Calculation modes</i> | Steady-state<br>Most calculations are limited to only allowing data entry at the beginning of the flowsheet (entries in a system). | Steady- and dynamic-state<br>Most calculations are limited to only allowing data entry at the beginning of the flowsheet (entries in a system). | Steady- and dynamic-state<br>It offers various degrees of freedom (e.g., data can be defined, at the beginning of the flowsheet, at the outputs, making combinations, etc.). |
| <i>Available resources</i>                | It features material generated by third parties. Most of the material is in English and is not intended for beginning learners.    | It has material generated by third parties. The material is available in the languages of English, Portuguese and Spanish.                      | It has official material from the company and material generated by third parties certified by them.   |

## II. DIQ-UMAG CASE STUDY

Our case study was carried out in the Project Engineering class in the final year, aiming to develop, apply, analyze, model, simulate and evaluate a preliminary basic engineering Project. Through project-based learning, each student plays a role as a project engineer in a team. The course has a total workload of ten hours per week, divided into two theoretical hours, two hours of exercises, and six hours of laboratory. The teaching coordinator carries out the syllabus between the theoretical hours and the exercises, while the laboratory hours are intended to simulate processes dictated by two support teachers.

### A. Creation of a DWSIM module

UMAG has an educational agreement with Google through the Google Workspace for Education Fundamentals. Therefore, it was decided to use Google Classroom [23] as a virtual classroom. Gómez-Goitia [24] indicates that some of the advantages of using Google Classroom as a virtual platform: i) ease of classroom configuration: an invitation to students, notifications and questions in the Announcements section, uploading of documentation; ii) good classroom organization: friendly and instinctive graphical interface for the user, the tasks to be performed are seen in the Work section or calendar, Classroom link with Google tools such as Gmail, Drive, Calendar; iii) multidirectional communication system: presents fluent communication between teachers and students; by sending notifications, teachers can initiate discussions or solve doubts online, and on the other hand, students can support each other online; and iv) data security: Classroom is free, data is kept safe on Google servers and services, student information is not used to create advertising profiles and data is protected according to the Google Workspace Agreement [25].

The module was created two weeks before formal classes, so teachers had to migrate tutorial material from Aspen HYSYS to DWSIM quickly. Within the literature review, there was material available on the official DWSIM webpage [22], in addition to the support of the creator and developer of the software Daniel Medeiros [26], and with the notes in Spanish from the Center for Computer Applications and Modeling in Engineering, Argentina [27].

Firstly, the planning and creation of module topics began; secondly, with the migration of the tutorials, the video tutorials were created consecutively. Table III shows the module's content; it is important to highlight the logical order of learning, starting from knowing the DWSIM environment, simulating the unit operations individually, and then simulating a chemical plant in a steady-state model. The order of the laboratory sessions was divided into two blocks, each one led by a teacher. Each block was divided into three stages: introduction to the topic and tutorials (synchronous); tutoring through the support of written material and video tutorials, with online assistance from the teacher (asynchronous); and closing of the block with a discussion of what has been learned (synchronous). Subsequently, students could independently review the tutorials through Google Classroom and YouTube.

### B. Creation of video tutorials

For the creation of video tutorials, a literature review was undertaken on the Internet about possible free tools for recording and editing videos, in addition to good practices in video tutorials. Regarding the recording tools, the OBS Studio software was chosen for recording [28], while, for editing, the OpenShot editor [29] was used.

Regarding the video tutorial production sequence, the guidelines described by Bengochea and Medina [30], Arguedas-Matarrica and Herrera-Molina [31], and Tuesta-Durango *et al.* [32], to create a workflow according to the needs of the module were followed. The sequence performed for the creation of video tutorials is listed below:

1. Preparation of slides with the tutorial presentation included presenting the learning objectives, theoretical framework (if necessary), and a case study to simulate.
2. Script elaboration of the teacher's voice that follows the recording sequence.
3. The tone of voice rehearsal, to make sure it is in an active voice, with clear and simple language.
4. Recording process with OBS Studio.
5. Editing process in OpenShot; the video tutorials were divided into capsules of a maximum of 15 minutes.

TABLE III  
CONTENT OF THE DWSIM MODULE.

| Topic                               | Purpose  | Material   |
|-------------------------------------|--|--|
| <i>Resources</i>                    | How to install DWSIM. Get familiar with the Google Classroom environment.  | Links from the DWSIM website, and YouTube videos.                                      |
| <i>Introduction to DWSIM</i>        | Know the environment and simulation flowchart. Understand the selection of thermodynamic models in simulation.                     | Presentations, written material, five tutorials with their respective videos.          |
| <i>Fluid mechanics</i>              | Simulate unit operations and fluid mechanics devices (pump, turbine, pipes, valves) available in DWSIM.                            | Presentations, written material, four tutorials with their respective videos.          |
| <i>Logic operators and reactors</i> | Simulate the logic operators and reactors available in DWSIM.  | Presentations, written material, five tutorials with their respective videos.          |
| <i>Assessment 1</i>                 | <b>Simulation of an Ideal Rankine Cycle.</b>   | <b>Written material and Google Form.</b>   |
| <i>Heat transfer</i>                | Simulate unit operations and heat-transfer devices (heat exchanger) available in DWSIM.  | Presentations, written material, one tutorial with their respective video.             |
| <i>Mass transfer</i>                | Simulate unit operations and mass transfer devices (columns) available in DWSIM. Learn how to use the ChemSep to simulate columns. | Three tutorials with their respective videos.  |
| <i>Steady-state chemical plant</i>  | Apply what you have learned, simulating a simplified chemical plant in a steady state.   | Presentations, written material, a tutorial with its respective video, and case study. |
| <i>Assessment 2</i>                 | <b>Extractive distillation simulation with ChemSep in DWSIM.</b>   | <b>Written material.</b>   |

It was decided to create a channel on the YouTube platform to guarantee better access to the audiovisual material generated. The material was uploaded and published, initially, privately (viewing only for students and teachers), developing a virtual interaction with the students thanks to rating systems such as the "Like" and "Comments" option [33]. In addition, facilitating both access to the video tutorials and the rapid replication of tutorials since the students used an additional device to the computer such as a smartphone or tablet for this.

### C. Assessment tools

Table III shows the two summative evaluations carried out to evaluate what has been learned. After the fourth topic, the first assessment was carried out that consisted of an asynchronous online individual test. The students simulated an ideal Rankine cycle in DWSIM, applying what they had learned to date; an online Google Form was used for the students to enter the answers. Through the Google classroom, they would upload their simulation files. The second assessment consisted of simulating individual coursework; a maximum delivery period of 10 days was set. The students had to simulate an extractive distillation and sent their simulation files and spreadsheet with requested graphics by email. The arithmetic average of these assessments corresponded to 20% of the final grade for the Project Engineering course.

As a formative assessment, a type forum with pragmatic dialogue [34] was organized to discuss the advantages and disadvantages of the DWSIM simulator, reflect on how to design, model, and simulate a chemical plant in a steady-state process simulator. The Meet platform was used; one of the teachers was the moderator, while the second teacher was the technical support. Each student was given five minutes to present the type of reactive distillation simulated in DWSIM and deliver a brief personal conclusion on the advantages and disadvantages of working with DWSIM. Subsequently, it was passed to the discussion forum, where each participant (including teachers) answered the following questions:

1. What are the advantages of a process simulator?
2. What are the problems encountered when performing a simulation in DWSIM, and how can they be solved?
3. What constructive criticism can you give us to improve the taught module?

The video call ended with a certificate delivery to prove that each student completed the DWSIM module at an intermediate user level.

In the Project Engineering course, the project developed by the students was to carry out reverse engineering of producing ammonia with green hydrogen and determine its maximum purchase price destined for Japan. The process was simulated in DWSIM to estimate the material balance and investment.

Finally, an anonymous survey was answered by the students after completing the Project Engineering course. The goal was to analyze whether they applied what was taught in the DWSIM module and know the level of satisfaction with the teaching performance. This survey was conducted in Google Form divided into:

- i) Request for consent to use the respondent's information for teaching and scientific research purposes.

- ii) Demographic data.
- iii) Evaluation of the DWSIM module regarding the use of the DWSIM simulator.
- iv) Application of what has been learned in the Project Engineering course.

### III. YOUTUBE CHANNEL DIQ\_DWSIM

As described in the previous section, a YouTube channel was created as DIQ\_DWSIM [35]. At first, the videos were uploaded in private mode so that only the students and teachers of the module had access to them. However, when the academic semester ended, it was decided to launch the channel publicly as an open online resource available to the YouTube community. The reasons behind this decision were to promote the image of DIQ on the Internet, generate an academic audiovisual resource in Spanish with free access, and offer a free online course that covers topics of process simulation in chemical engineering. Part of the reasons mentioned above are solutions to barriers that we detected, which prevent online learning of open source software such as DWSIM for any beginning user and finding teaching support material.

## IV. RESULTS

### A. DWSIM module results

Only three students took the Project Engineering course and, therefore, the DWSIM module. The age range is between 23 and 25 years old, divided into  $\frac{2}{3}$  female and  $\frac{1}{3}$  male from the gender perspective. From the internet connection point of view, two connections came from Punta Arenas city, while the other student connected from the capital Santiago de Chile.

The assessment scale in the UMAG uses a scale from 1 to 7, with a 60% approval requirement. The first summative assessment had an arithmetic mean of 5.30 with a standard deviation of 1.14. The second summative assessment had an arithmetic mean of 4.90 with a standard deviation of 0.55. The final grade for the average module was 5.10, with a standard deviation of 0.38.

The discussion forum had positive results where the contents learned in the module were reinforced, theoretical concepts were clarified, interpretation of the simulation concerning the real process, the role of the chemical engineer in the simulation of processes, among others. The only constructive criticism delivered throughout the course was that the asynchronous time was not enough to carry out the tutorial completion, generating stress in the students. The reason for this situation is that the teachers were almost parallel creating the video tutorials, so the students did not have the option of entering the YouTube channel before class to review the tutoring, but only after the session of classes.

At the end of the academic year, an anonymous survey was sent to the students, divided into the DWSIM module and the application of what was learned. In the first section, the students responded with a Likert scale to 18 statements divided into three subsections. The responses to be selected were valued as: Totally disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, and Totally agree = 5. Table IV shows the arithmetic mean and standard deviation by assertion, obtaining the following results:

- In their entirety, the students answered the statements between “Agree = 4” and “Strongly agree = 5”.
- For subsection 1, regarding learning with DWSIM, a total average of 4.81 and a standard deviation of 0.40 were obtained, indicating that the students acquired the technical ability to simulate processes with this simulator.
- For subsection 2, in terms of content and online teaching modality, a total average of 4.78 and a standard deviation of 0.43 were obtained. This means that the prepared material, the teaching modality, and the virtual classroom were ideal for the students.
- For subsection 3, regarding teaching performance, a total average of 4.87 and a standard deviation of 0.35 was obtained. This means that the teachers’ expertise, the ERT methodology implement, and the discussion forum were pertinent so that the students acquired the technical skills of process simulation.

TABLE IV  
AVERAGE AND STANDARD DEVIATION OF THE STATEMENTS ANSWERED BY THE STUDENTS WITH THE LIKERT SCALE

| Statement  | Average     | Std. Dev.   |
|--|-------------|-------------|
| <b>1. As for learning with DWSIM</b>   |             |             |
| You can establish the learning of mathematical concepts and methods associated with the simulation of processes through the use of DWSIM                                       | 4.67        | 0.58        |
| The learning of the theoretical contents associated with the simulation of processes in plants or chemical processes can be improved with a commercial simulator such as DWSIM | 5.00        | 0.00        |
| With a commercial simulator such as DWIM, greater practicality and applicability of learning can be obtained, compared to the option of reading books and documents            | 4.67        | 0.58        |
| Knowing and handling the DWSIM simulator to perform process simulation increased the degree of motivation as a student in this topic   | 5.00        | 0.00        |
| An open-source simulator like DWSIM improved the degree of autonomy of my non-face learning  | 4.67        | 0.58        |
| DWSIM has a user-friendly graphical interface, which makes the workflow instinctive  | 4.67        | 0.58        |
| Training with DWSIM has improved my technical skills as a future chemical engineer   | 5.00        | 0.00        |
| <b>Overall subsection 1</b>  | <b>4.81</b> | <b>0.40</b> |
| <b>2. As regards to the content and online teaching</b>  |             |             |
| The Google Classroom (Virtual Classroom) was an ideal alternative, with easy access to the material and user-friendly  | 4.67        | 0.58        |
| The written material (practical tutorials and support material) delivered was explicit, explanatory, and didactic for my learning in process simulation                        | 5.00        | 0.00        |
| The video tutorials helped me in my learning both synchronous (real-time online) and asynchronous (outside class hours)  | 4.67        | 0.58        |
| The video tutorials were of high quality, providing both the theoretical knowledge and the practical sequence of performing simulations in DWSIM                               | 4.67        | 0.58        |

CONTINUATION OF TABLE IV

| Statement  | Average     | Std. Dev.   |
|--|-------------|-------------|
| The fact that the video tutorials were available on YouTube made access faster and not difficult                             | 5.00        | 0.00        |
| The online evaluations were relevant both for the content learned and adequate to be carried out online                      | 4.67        | 0.58        |
| <b>Overall subsection 2</b>  | <b>4.78</b> | <b>0.43</b> |
| <b>3. As for the teacher performance</b>   |             |             |
| Teachers have great expertise in process simulation  | 5.00        | 0.00        |
| The teachers' way of teaching was of high quality, with a dynamic that achieved both my attention and my motivation to learn | 4.67        | 0.58        |
| The teachers clarified all my doubts in time   | 4.67        | 0.58        |
| Teachers turned in my evaluations on time  | 5.00        | 0.00        |
| For the evaluation of my learning, I found that the realization of a discussion forum about what I learned was ideal         | 5.00        | 0.00        |
| <b>Overall subsection 3</b>  | <b>4.87</b> | <b>0.35</b> |

Two open questions were asked: What did you like the most about the module? And, What did you like the least about the module? Regarding the first question, the students thought they liked: the prepared material, the video tutorials, and the online teaching support to clarify doubts. In the second question, the students felt that they did not like that the classes were only once a week, having almost four chronological hours of an online session, having limited time to complete the video tutorials calmly. Finally, on a scale from 1 (Extremely dissatisfied) to 5 (Extremely satisfied), an average rating of 4.3 was obtained from the DWSI module.

In the second section, the students answered two closed questions (Yes / No) and two open ones. The closed questions were: DWSIM, Did it help you solve your case study, either in part or in its entirety? And, When applying a commercial simulator like DWSIM in a basic engineering project, did it help you understand the importance of process simulation as a chemical engineer? In both, the students answered that Yes.

On the other hand, the first open question was: How did you use DWSIM? And the students answered:

Student 1: *“Flow diagram, process modeling, and determination of necessary raw material flows.”*

Student 2: *“To be able to simulate the Haber-Bosch process, and to know the amount of raw material that you would need under certain conditions.”*

Student 3: *“To simulate an ammonia cycle and obtain operating parameters.”*

These responses confirm that the students used DWSIM to solve the case study in Project Engineering. The second open question was: Tell us if you had any inconvenience when carrying out your simulation in DWSIM with an example, where the students answered:

Student 1: *“When running a complex simulation, many times the program would freeze or quit unexpectedly. In addition, when placing data or objects in the simulator, it must*

*have a few seconds of “assimilation” with the change, which leads to a delay or the possibility of the program sticking.”*

Student 2: *“When I had some difficulty, the practical material was very helpful. Especially when certain equipment had to be used, and I did not remember which variables to add”.*

Student 3: *“The general downside of the software is that it sometimes gets stuck.”*

These responses were expected due to experience running simulations in DWSIM. The software performs calculations sequentially, from left to right and not vice versa, so any change in variables made in any part of the process will have to restart the rest of the calculations throughout the process. Also, when using equipment such as reactors or distillation columns, which have more complex calculation algorithms, DWSIM has a lower capacity than Aspen HYSYS in computational robustness. Finally, it is essential to mention that the user must understand the assumptions and restrictions of the simulator.

### B. YouTube channel results

The DIQ\_DWSIM channel was launched on August 10, 2020, with 19 tutorials broken down into 50 video tutorials; it currently has 152 subscribers and over 20,000 total views among the videos uploaded to the channel (reported on April 14, 2021). Google Analytics [36] was used. The following tables and figures show the data obtained about the visualizations made in the DIQ\_DWSIM channel.

TABLE V  
DETAIL OF THE OBTAINED DATA IN GOOGLE ANALYTICS

| Category                          | Statement   |
|-----------------------------------|---|
| Audience age                      | The videos are mostly viewed by an audience aged 18 and 24 (77.1%), followed by an audience aged between 25 and 34 (12.4%). A better detail with the age ranges can be seen in Fig. 2.  |
| Audience genre                    | From a gender point of view, the audience on the channel is 64.9% men and 35.1% women.  |
| Geographical area                 | Of the views, the audience originates mainly from Mexico (72.9%), followed by Colombia (5.4%) and Spain (2.2%). A more detailed breakdown of the geographic area of the visualizations can be seen in Fig. 3.   |
| Video (average percentage viewed) | Tutorial 17 (Rigorous distillation column) is the tutorial with the highest average percentage seen (37.02%, 43.9%, and 47.57% in its three sections, respectively). In comparison, tutorial 19 (Liquefied natural gas plant) is the lowest Average percentage seen (15.53%, 20.37%, and 21.91% in its three sections, respectively). |
| Visualizations overview           | Fig. 4 shows the increase in views from August 2020, in addition to block increases in specific periods.  |

The results obtained were expected in the categories analyzed in tables and figures because:

- The highest percentage of views obtained by age range corresponds, in general, to that of an average undergraduate student and young professionals to whom the channel is focused.
- The first three countries with the highest views are Spanish-speaking.
- The most sought-after tutorials are simulations of complex equipment such as distillation columns, but

at the same time, tutorials on specific topics are the least sought after.

- The timeline in Fig. 4 agrees with what happened in the channel. First, in August 2020, the channel is opened to the public. Second, the sudden block changes in the number of views are due to other courses in other regions (Mexico and Colombia) addressing simulation processes.

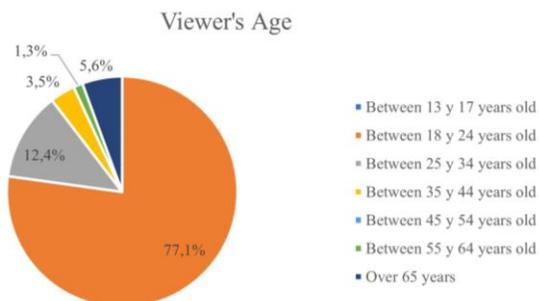


Fig. 2. Age range of viewers on the DIQ\_DWSIM channel.

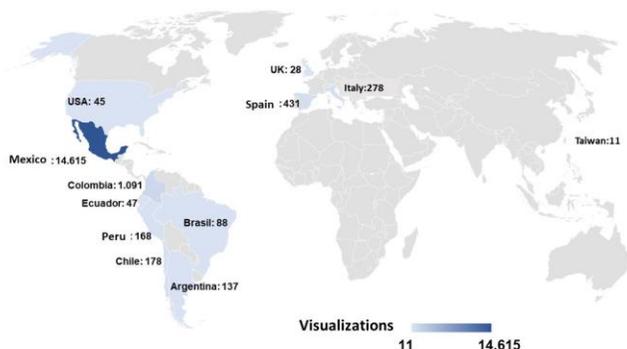


Fig. 3. Geographical map of the location of the DIQ\_DWSIM channel visualizations.

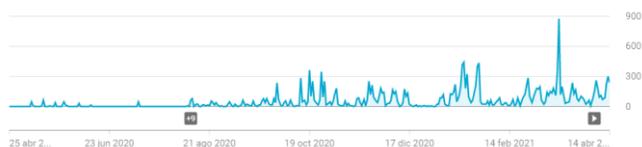


Fig. 4. DIQ\_DWSIM channel visualization overview.

As a result of the impact of this channel, collaborations were carried out in two Latin American universities: Universidad de Santiago de Chile and Universidad Veracruzana, Mexico. To analyze the effect on the audience of our channel, an anonymous survey divided into:

- Request for consent to use the respondent's information for teaching and scientific research purposes.
- Demographic data.
- Evaluation of the YouTube channel.

This survey was sent to the students of these universities, and we also invited our audience by uploading a video titled "DIQ\_DWSIM we want to know your opinion" [37].

The total number of people surveyed was 94, where 23% have an age range of 17 to 20 years, 64% have 21 to 23 years, and 13% are older than 23 years. From a gender point of view, 55% identify as female and 45% as male. More than 80% of those surveyed are pursuing undergraduate or graduate degrees related to chemical engineering or process engineering. 93% of the respondents' study in Mexico, 2% study in Chile, and 4% of the respondents are not students.

The first question was to indicate the reasons why they visited our channel, which 63% of the respondents stated that it was used as the primary material to learn DWSIM, 55% of the respondents indicated that it was used as complementary material to understand DWSIM, and 41% of respondents told it was to self-learn about DWSIM.

The second question involved categorizing five statements regarding the content of the videos. Respondents responded with a Likert scale with the categories of: Totally disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, and Totally agree = 5. Table V shows the arithmetic mean and standard deviation by assertion, obtaining the following results:

In their entirety, the students answered the five statements between the ranges of "Neutral = 3", "Agree = 4," and "Strongly agree = 5".

- For the first statement, a total average of 4.27 and a standard deviation of 0.80 were obtained, indicating that respondents agree that both the form and structure of the video tutorials were adequate to focus.
- For the second statement, a total average of 4.35 and a standard deviation of 0.83 were obtained. This indicates that the video tutorials served as a resource to understand the simulation of processes.
- For the third statement, a total average of 4.04 and a standard deviation of 0.94 were obtained. This indicates that the respondents agree that both the voice and the tone of the teacher's voice-over were adequate.
- For the fourth statement, a total average of 4.17 and a standard deviation of 0.89 were obtained. This indicates that the respondents agree that the length of the videos was optimal.
- For the fifth statement, a total average of 4.34 and a standard deviation of 0.78 were obtained. This tells us that respondents agree that the simulated processes in DWSIM represent real industrial processes.

The next question was whether they replicated the tutorials watched on the channel, to which 68% of those surveyed indicated that they did. Of this group, 31% indicated that they never had simulation problems, 27% indicated that they rarely had problems, 36% indicated that they sometimes had simulation problems, 5% almost always had problems, and 1% always had problems. Among the issues reported they were related to convergence. Only problems were reported in replicating tutorial 14, where two respondents indicated a

discrepancy with the data provided in the video with respect to the results they simulated in DWSIM.

Of the 19 tutorials available on our channel, 7% of the respondents answered that they did all the tutorials, 6% of the respondents carried out between 13 to 18 tutorials, 27% of the respondents carried out between 7 to 12 tutorials. A 60% carried out between 1 to 6 tutorials.

From the subscription point of view, 80% of respondents are subscribed to our channel, and 44% of respondents have shared our videos on their social networks or among their contacts.

All respondents indicated that they would like to see more video tutorials. The most suitable topics were more complex industrial processes, operations with chemical agents in reactors, and distillation columns; They also indicated the replication of case studies from academic books and the use of complementary tools. It is also important to mention that some respondents stated that they would like to see video tutorials of other commercial software such as Aspen HYSYS or AVEVA (used at the Universidad Veracruzana).

Finally, all those surveyed consider that the audiovisual material seen on the channel has helped them understand how a process simulator works. In general, respondents have rated their degree of audience satisfaction on a scale from 1 (extremely dissatisfied) to 5 (extremely satisfied), with an average of 4.3.

TABLE VI  
AVERAGE AND STANDARD DEVIATION OF THE STATEMENTS ANSWERED BY RESPONDENTS ABOUT THEIR OPINION ON THE DIQ\_DWSIM YOUTUBE CHANNEL WITH A LIKERT SCALE

| Statement   | Average     | Std. Dev.   |
|---|-------------|-------------|
| <b>1. Regarding the content of the videos on our YouTube channel</b>                                      |             |             |
| The form and structure of the video tutorials are relevant to get my attention and focus on their content | 4.27        | 0.80        |
| The video tutorials helped me understand the importance of process simulation in chemical engineering     | 4.35        | 0.83        |
| The teacher's voice and tone was correct to keep me attentive to the video                                | 4.04        | 0.94        |
| The length of the videos was optimal  | 4.17        | 0.89        |
| The tutorials shown in the videos provide examples close to the reality of an industrial process          | 4.34        | 0.78        |
| <b>Overall</b>  | <b>4.33</b> | <b>0.85</b> |

## V. DISCUSSION OF THE RESULTS

### A. Emergency Remote Teaching in process simulation

According to what was indicated by Hodges *et al.* [38] and Portillo *et al.* [39], to evaluate the ERT methodology, one must focus on the context, the input elements, the learning process, and the final product. The teachers' opinion is that thanks to the free applications available on Google and the selection of DWSIM as an alternative process simulator, both the context and the input elements were implemented correctly.

Both the summative and informative assessments of the module indicate that the ERT methodology implemented by the teachers was the pertinent one to achieve that our students

acquired the technical skills of process simulation before graduating.

Regarding the summative assessments, both the resulting averages per assessment and the total average of the module indicate the students' excellent performance. It is important to tell that the requirement in DIQ courses is 60%, that is to say, that the passing grade is 4.0, and to be exempted from a course, the total grade point average must be equal to or greater than 5.0. Some challenges presented in these evaluations were that the time established to complete the tests was not sufficient; for the first test, a time of 2 chronological hours was given while the students finished in 3 hours, and, for the second test, 5 days was initially given while the students finished in 10 days. The reason for delivering on a more extended deadline was the high academic load in the other courses.

Concerning the discussion forum, we confirmed that the students learned what was seen in the DWSIM module. Video tutorials are highlighted to complement the written material, favoring independent learning, reinforcing theoretical concepts, and covering possible learning gaps. In addition, as Jiménez-Castillo and Marín-Carrillo [40] describe from the teaching view, video tutorials avoid repetitiveness allowing the teacher to focus on the learning process of their students. Also, if the teacher carries out the video tutorials, both the reception of information and the learning by their students will increase.

The anonymous survey provides very positive results regarding the methodology implemented. All students agreed that the virtual classroom, the online support from teachers, and the video tutorials were ideal for learning to simulate with DWSIM. The results of the Likert scale assertions shown in Table VI confirm that learning with DWSIM, the online modality implemented, and the teaching performance was excellent; since there was a total general average of 4.33 and a standard deviation of 0.85. In addition, it is confirmed that they used DWSIM as a process simulator in their case study in Project Engineering, managing to simulate an ammonia cycle and performing different analyzes necessary to design a chemical plant.

The learning based on simulators implemented in the module agrees with that indicated by Borreguero *et al.* [41]) that commercial simulators make it possible for students to simulate real processes with complex and fast automatic calculations. Based on assumptions and restrictions of the software, this teaching type provides technical simulation skills that are key to a recently graduated chemical engineer entering the labor market.

### B. Impact of the DIQ\_DWSIM channel

The number of subscribers and views achieved to date is surprising, where almost 90% of the audience are university students and young professionals, and more than 80% come from Spanish-speaking countries. Therefore our channel has been beneficial for young beginners in DWSIM and process simulation. In addition, the first five minutes of each video are the most watched by viewers, meaning that they review what the video is about, what will be simulated, and based on this, they decide whether they continue to watch it or not. Here there is a difference with respect to a student spectator of a formal course and a self-taught spectator.

The anonymous survey that evaluated the opinion of the audience of our channel delivers positive and revealing results. First of all, it is formidable that the total of respondents is 94, compared to the DWSIM module of 3 students managing to increase our audience 30 times by simply launching our channel publicly. Several teachers have found our channel and used it either as primary or complementary material in their courses, confirming that we are right in our purpose of providing a Spanish-speaking free online learning resource.

In general, regarding the content of the videos, the respondents agree that they learned to use DWSIM through practical examples of industrial processes, the length of the videos, tone of the teacher's voice-over, the form, and structure of the videos. Videos are suitable for their attention and understanding. These results agree with case studies reported by Arguedas and Herrera [31], López [42], and Álvarez [43].

Most of the respondents simulated between 1 to 12 tutorials, representing 63% of the tutorials available on the channel. Only issues of replicating the simulation were reported in tutorial 19 due to video editing problems, which DIQ teachers knew in advance, as it had been detected in the DWSIM module. This video will be reviewed and modified in the future. Respondents rate the channel with an average of 4.3, on a scale of 1 (extremely dissatisfied) to 5 (extremely satisfied), as did the students of the DWSIM module. So we can point out that our channel satisfies what the audience expects in our video tutorials.

## VI. CONCLUSION

The Emergency Remote Teaching methodology implemented together with the simulation-based learning and the experience of teachers managed to deliver technical skills to students in process simulation. According to the assessment instruments carried out in the Project Engineering course, the selection of the alternative DWSIM software was the correct one to replace Aspen HYSYS. The creation of video tutorials and the DIQ\_DWSIM channel were key to the success of our objective and to deliver support material that third parties. The anonymous survey proved that two Latin American universities formally used it in their courses and YouTube users as well.

Undoubtedly, the COVID-19 pandemic has forced and awakened teachers to seek innovative ways to generate engaging content for student-centered learning. The creation of these video tutorials has not only managed to provide an immediate solution to our teaching emergency, but they have also served many teachers, students, and young engineers to learn about DWSIM and how to simulate industrial processes. As ways for the future, the DIQ teachers will propose to generate virtual laboratories to simulate other types of equipment, analyze their performance and the calculation equations behind them. These simulations can be used early course; thus, visual support would be delivered, complementing with the creation of video tutorials for the teacher, allowing more open resources in Spanish.

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