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Artículos científicos

SecuenciaLab: laboratorio de simulación para entrenamiento en manejo de sistemas de control electromecánicos

***SecuenciaLab: Simulation laboratory for training in the management of
electromechanical control systems***

***SequenceLab: laboratório de simulação para treinamento em gestão de
sistemas de controle eletromecânico***

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Resumen

Los laboratorios virtuales se han utilizado en la educación como sistemas de entrenamiento a través de prácticas/experimentos para desarrollar en los estudiantes habilidades o capacidades que permitan desempeñar una tarea aún no aprendida utilizando ciertos equipos a través de un modelo de enseñanza no presencial. Sin embargo, en México existe poca documentación respecto al desarrollo y/o utilización de esta tecnología. Para incorporar y evaluar la efectividad de esta herramienta tecnológica, el presente trabajo se enfocó en el desarrollo y evaluación del laboratorio virtual SecuenciaLab, el cual se implementó considerando dos elementos principales: 1) un simulador que funciona como una aplicación de escritorio para la creación, diseño y prueba de sistemas de control secuencial, enfocado a reforzar la educación de los estudiantes de nivel licenciatura o superior relacionados con la carrera de Ingeniería Mecánica Eléctrica, 2) una plataforma de aprendizaje para el control de prácticas, clases, reportes de evaluación, reportes de grupo y evaluación. La evaluación de la efectividad de la herramienta se realizó a través de pruebas piloto en el equipo de desarrollo junto a la asesoría de un grupo de docentes. Además, se efectuaron algunas pruebas preliminares con grupos de control para contrastar el desempeño y el aprendizaje de los estudiantes que utilizaron el simulador y aquellos que no lo hicieron. Los resultados indican que los estudiantes que utilizaron el laboratorio virtual SecuenciaLab obtuvieron una calificación promedio de 10.85 puntos más que quienes no lo usaron.

Palabras clave: comunicación, educación, herramientas, soporte.

Abstract

Virtual laboratories have been used in education as training systems through practices/experiments to develop skills or abilities in students that allow them to perform a new task or work that they have not yet learned using certain equipment, through a non-classroom teaching model. However, in Mexico, there is reduced documentation related to the development and/or use of this technology. To incorporate and evaluate the effectiveness of this technological tool, this work is focused on the development and evaluation of the SecuenciaLab virtual laboratory, which was implemented considering two main components: 1) a simulator that works as a desktop application for the creation, design, and testing of sequential control systems, focused on reinforcing the education of undergraduate students or graduated, related to the Electrical Mechanical Engineering career, 2) a learning platform,



to control practices, classes, evaluation reports, group reports, and evaluation. The evaluation of the effectiveness of the tool was carried out through pilot tests within the development team, together with the advice of a group of teachers. In addition, some preliminary tests with control groups in order to contrast the performance and learning of students, who used the simulator and those who did not use it.

The results of the study indicate that the students who use the virtual laboratory SecuenciaLab show a better academic performance which is 10.85 points more than those who did not use it.

Keywords: Communication, education, tools, support.

Resumo

Os laboratórios virtuais têm sido utilizados na educação como sistemas de formação através de práticas / experimentações para desenvolver competências ou habilidades nos alunos que lhes permitam realizar uma tarefa ainda não aprendida com determinados equipamentos através de um modelo de ensino não presencial. No entanto, no México, há pouca documentação sobre o desenvolvimento e/ou uso desta tecnologia. Para incorporar e avaliar a eficácia desta ferramenta tecnológica, este trabalho centrou-se no desenvolvimento e avaliação do laboratório virtual SequenceLab, o qual foi implementado considerando dois elementos principais: 1) um simulador que funciona como uma aplicação desktop de criação, projeto e teste de sistemas de controle sequencial, com foco no reforço da formação de alunos de graduação ou superior relacionados à carreira de Engenharia Elétrica Mecânica, 2) uma plataforma de aprendizagem para o controle de práticas, aulas, relatórios de avaliação, relatórios grupo e avaliação. A avaliação da eficácia da ferramenta foi realizada por meio de testes pilotos na equipe de desenvolvimento em conjunto com a assessoria de um grupo de professores. Além disso, alguns testes preliminares foram realizados com grupos de controle para comparar o desempenho e a aprendizagem dos alunos que usaram o simulador e os que não usaram. Os resultados indicam que os alunos que usaram o laboratório virtual SequenceLab obtiveram uma pontuação média de 10,85 pontos a mais do que os que não usaram.

Palavras-chave: comunicação, educação, ferramentas, suporte.

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Introduction

A training system is made up of a set of methods and activities carried out in an orderly manner to allow the individual to develop certain skills or competencies so that they can perform a new task. This training process requires time, effort and dedication, and can be carried out in a directed and even self-taught way, since with the advancement of information technology [IT] new educational alternatives have emerged that can be specified without the need for contact physical with an advisor or specialized team.

In this sense, and according to Budai and Kuczmann (2018), conventional laboratories have long been the places used to learn and practice on specific branches of human knowledge. However, these spaces have some significant disadvantages, such as 1) initial cost, 2) cost of maintenance, 3) heavy time and physical dependence on the laboratory, 4) lack of availability of limited equipment and materials, and 5) consumption of electrical energy. However, by incorporating various digital technologies focused on this area, it has been possible to develop non-traditional alternatives that solve these limitations through the creation of virtual laboratories.

A virtual laboratory is a computer system used as a pedagogical tool aimed at teachers and students, which aims to simulate the environment of a real laboratory and which, through interactive simulations, allows the development of laboratory practices and experiments (Stark, Bisták and Kučera, 2018).

According to (Achuthan et al., 2011), the interaction in the virtual laboratories allows the user to actually carry out the practice / experiment, since progress is only made if the program is provided with the information it needs to carry out the required transformations. In addition, the laboratory is brought to the screen of a device, which allows each student to experiment and comply with the same practices as many times as necessary to reinforce the knowledge acquired in the classroom.

For this reason, this paper presents the design of a software to promote virtual learning in the Sequential Control Systems course-workshop of the degree in Electrical Mechanics Engineering, which is taught from the eighth semester at the University of Guadalajara.

The main objective of this software is to create a virtual simulator focused on students so that they can remotely and accurately recreate the behavior of the control and force systems studied in the course. Likewise, with the use of the simulator, students will have the possibility of reinforcing knowledge as many times as they deem necessary and in the way

they consider most appropriate according to their ways of learning. With this simulator, in addition, it is intended to solve the following problems: 1) solve their doubts and improve their academic performance, 2) allow students to work with the team before doing physical practices, 3) encourage the use of current technologies for educational benefit, and 4) allow the use of the laboratory on a 24/7 schedule.

Finally, to assess the effectiveness of the simulator, a sample of the evaluation formats on the tool and the general course applied to obtain feedback from the students is presented, and the main results obtained are shown, as well as future lines of work.

Literature review

Currently, there are a significant number of virtual laboratories in operation, which - according to Medina, Saba, Silva and de Guevara Durán (2011) - can be classified into four types:

- 1) Remote Virtual (RE): Allows access to a real physical system from a remote location using the internet.
- 2) Virtual local (VL): A software is used to simulate the experiments that could be carried out in a physical system, but without the need to install a simulation environment.
- 3) Virtual distributed (VD): In this all the simulation software is installed on a web server and the users exclusively execute the interface.
- 4) Virtual Hybrid (VH): It is a combination of the other types of virtual labs.

Table 1 shows some laboratories. Note that the focus is on training through methods, activities or exercises ordered in a certain way so that students can develop certain skills in the field of engineering. Due to the needs of the Sequential Control Systems course-workshop, it was decided to develop a virtual local laboratory.

Tabla 1. Características de *software* educativo

Software	Características	Usuarios
Controlly propuesto en Álvarez Ariza (2015)	Plataforma virtual monolítica (VL) para el diseño de sistemas de control automático SISO y MIMO.	Estudiantes de nivel superior y profesores en el campo de ingeniería electrónica.
QET propuesto en Khan, Jaffery, Hanif y Asif (2017)	Plataforma virtual híbrida (VH) que incorpora los fundamentos de los sistemas de control basada en MATLAB para enseñar los conceptos de orientación, navegación y control de un cuadrotor a estudiantes de pregrado.	Estudiantes de nivel superior y profesores en el campo de ingeniería mecánica.
DSBlock propuesto en Álvarez Ariza (2019)	Plataforma virtual híbrida (VH) de código abierto para el aprendizaje de sistemas integrados basados en visualizaciones de algoritmos y controladores de señal digital.	Estudiantes de nivel superior y profesores en el campo de ingeniería electrónica.
AutomatL@bs propuesto en Guzmán <i>et al.</i> (2010)	Red de laboratorios virtuales híbridos (VH) para la enseñanza de temas de control automático mediante la integración de los recursos que aportan los grupos que participan en el proyecto.	Estudiantes de nivel superior y profesores en el campo de control automático.
Remote laser laboratory propuesto en Titov, Smirnova, Glotov y Golovin (2012)	Prácticas virtuales remotas (RE) para realizar experimentos de ingeniería láser de forma segura.	Estudiantes de nivel superior y profesores en el campo de ingeniería láser.
Remote laboratory for digital holographic metrology propuesto en Wilke <i>et al.</i> (2011)	Prácticas virtuales remotas (RE) para metrología holográfica digital.	Estudiantes de nivel superior y profesores en el campo de ingeniería optoelectrónica.

Fuente: Elaboración propia

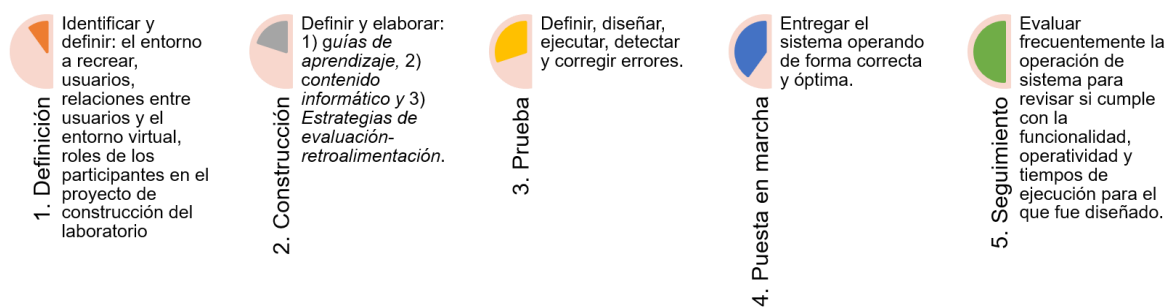
Methodology

Based on the elements raised in Yang (2011) and Ecu-Red (2014-2019), the SequenceLab laboratory involves the combination of the following software development methods: waterfall, successive versions and prototypes. In the definition phase of the project, two main objectives were identified: 1) to develop a virtual laboratory and 2) to develop a learning platform.

Methodology for the virtual laboratory

To develop the virtual laboratory, the methodology proposed in Ecu-Red (2014-2019) was used, which is summarized in Figure 1.

Figura 1. Fases de desarrollo de SecuenciaLab



Fuente: Elaboración propia

- *Definition phase.* The objective was proposed that the students of the course-workshop Sequential control systems of the Electrical Mechanics career can work within a virtual environment with simulations of the sequential control machines that are used in the physical laboratory for the elaboration of their practices / experiments, in order to help them improve their practical skills in the use of required equipment.
- *Construction phase.* For each of the sequential control machines physically available for the course (using a prototype methodology), the set of learning guides and computer content were defined and elaborated as explanatory documents and simulations with descriptive information, operating parameters, characteristics and functioning . In order to define and elaborate the evaluation-feedback strategies for the construction phase, the following was carried out:

1. The display environment was defined. The Visual Studio® Community 2019 Integrated Development Environment [IDE] was chosen.
 2. The virtual laboratory was implemented. Using the Unity engine version 2019.1.5f as the main programming logic tool, the simulator models were developed in Blender 2018, Adobe Photoshop and Adobe Illustrator.
 3. Infrastructure management processes were defined. In order for the virtual laboratory to work smoothly, accurately and with a minimum probability of error, the functionality of each model was programmed with the languages GitHub, C #, JavaScript and Python.
 4. The parameterization processes were defined. In this case the set of technical requirements for correct use.
 5. The evaluation and feedback strategy was designed. Through the use of a qualitative form for students to evaluate the operation of the virtual laboratory and the support material (learning guides and computer content).
- *Testing phase.* Functionality, security, scalability and maintenance tests were carried out.
 - ● *Start-up phase.* The virtual laboratory was delivered operating correctly and optimally.
 - ● *Follow-up phase.* It corresponds to the periodic evaluation of functionality and operability.

Methodology for the learning platform

The view controller model [MVC] was used - considering the elements proposed in Churi, Wagh, Kalelkar and Kalelkar (2016) - and prototype development, for which the following phases were considered.

- *Analysis.* At this stage, the analysis of the problem was reviewed, as well as the development of the IEEE standards for the collection of data requirements. In addition, interviews were conducted with the client to define in detail the specific requirements that had to be satisfied.
- *Design.* The structure and operation of the website, a comprehensive management platform, was designed and planned. The design of the platform covered from the layout of the views, the definition of the colorimetry, the design of the components, etc.



- *Construction.* The entire development of the web application was carried out, from the layout of the views to the programming of all the functionalities.
- *Testing.* In order to corroborate the correct operation of all use cases.

The technologies used in the implementation of the platform were PHP and HTML for the client-server architecture. For the exchange of information between the application and the database, the MySQL database engine was used with the SQL language, as well as the JavaScript, Ajax, JQuery, Bootstrap 4 (main framework of the platform) languages.

Instruments used for development and testing

For the development and testing of the application, the following electronic devices (computers) with the operating system Windows 7, Windows 8.1 and Windows 10, based on 64-bit processors, were used. The minimum RAM required per computer for the development and testing of this system was 4 GB on average (DDR2 and DDR3), with processing speeds above 2.0 GHz.

The computers on which this project was developed require specific software installed: Unity, Blender, Adobe Photoshop and Adobe Illustrator. Due to the characteristics of the simulator, it was possible to modulate the graphic quality of the simulation models, as well as the particles, the animations, among other components. This allowed the software to be run on a wide variety of computers with limited resources. Table 2 shows the requirements and minimum technical specifications to run the simulator properly.

Restrictions

SequenceLab (simulator) can only be run on Windows 64-bit operating systems from version 7 or higher. The system is capable of working in parallel with other applications, as long as the hardware allows it. Any user who downloads the simulator will be able to make full use of all its functionalities.

Tabla 2. Requisitos técnicos para la ejecución de SecuenciaLab (laboratorio virtual)

Requisitos mínimos	
Sistema operativo	Windows 7 / Windows 8 / Windows 10 64-bit
Procesador	Intel Core™ i3 o AMD Phenom™ X3 8650
Memoria	4 GB RAM
Almacenamiento	500 Mb disponible en disco duro
Resolución	1024 x 768 mínima resolución de pantalla
Requisitos recomendados	
Sistema operativo	Windows 7 / Windows 8 / Windows 10 64-bit
Procesador	Intel® Core™ i5 o AMD Phenom™ II X3 o superior
Memoria	6 GB RAM
Almacenamiento	500 Mb disponible en disco duro
Resolución	1024 x 768 mínima resolución de pantalla
Requisitos óptimos	
Sistema operativo	Windows 7 / Windows 8 / Windows 10 64-bit
Procesador	Intel® Core™ i7 o AMD Phenom™ II X5 o superior
Memoria	8 GB RAM
Almacenamiento	500 Mb disponible en disco duro
Resolución	1024 x 768 mínima resolución de pantalla

Fuente: Elaboración propia

From a process perspective, SequenceLab was developed according to the spiral software development process model, an evolutionary model in which there is practically a combination of the prototyping model with the sequential linear model. The spiral model is

adaptable and places great importance on risks, hence this software, used for educational purposes, is expected to be free of flaws in the future.

Experimental results

The application has served to support the students of the Electrical Mechanical Engineering career of the University Center of Exact Sciences and Engineering (CUCEI) of the University of Guadalajara (UdeG), since it offers the possibility of interacting easily and without risks with a virtual model of the sequential control equipment available in the laboratory. In addition, this application allows to solve the problem of the lack of availability of the physical equipment for the preparation of the practices, and serves as a support as a tool to reaffirm the knowledge acquired during the explanation of the course.

Within the learning platform there are two types of users: teachers and students. According to what is indicated in table 3, each of the users within the learning platform has different activities.

Note that teachers are the users with the highest number of activities, while the number of student assignments depends on the deliverables assigned by the teacher.

Feedback evaluation

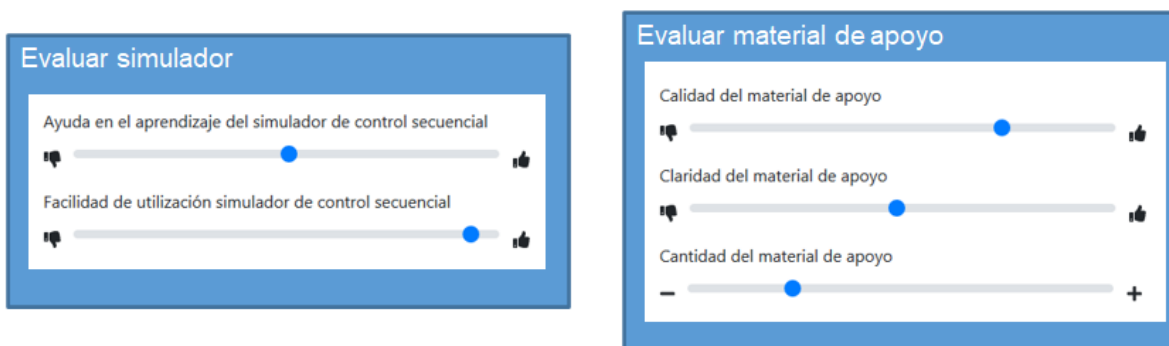
In order to quantitatively evaluate the functioning of the virtual laboratory and the support material (learning guides and computer content), a group of students - who have used SequenceLab previously within their Sequential Control Systems course-workshop - were asked to complete the evaluation survey of the tool developed. Figure 2 shows the format used for this activity.

Tabla 3. Características de los usuarios

Tipo de usuario	Formación	Habilidades	Actividades
Alumnos	Estudiante de nivel licenciatura o superior registrado en el sistema que cuente con un dispositivo con Windows.	-Habilidades básicas para el uso de plataformas web. -Habilidades intermedias para la interacción con <i>software</i> de simulación (como videojuegos)	-Inicio de sesión. -Afiliación a una clase creada. -Resolución y entrega de actividades entregables. -Generación y simulaciones de sistemas de control secuencial.
Profesores	Profesores de nivel licenciatura o superior registrados en el sistema que cuenten con un dispositivo con Windows.	-Habilidades básicas para el uso de plataformas web. -Habilidades intermedias para la interacción con <i>software</i> de simulación (como videojuegos).	-Inicio de sesión. -Creación y gestión de clases. -Creación, asignación, evaluación y gestión de entregables -Creación y gestión de copias de seguridad del sistema -Generación de reportes -Generación y simulaciones de sistemas de control secuencial.

Fuente: Elaboración propia

Figura 2. Encuesta de evaluación



Fuente: Elaboración propia

Note that in the evaluation survey the student assesses each criterion using a sliding bar, which avoids bias in the responses, since at no time can a numerical weight be assigned. Table 4 shows the numerical rating corresponding to the evaluation.

The results of the survey were as follows: the simulator scored “average” in help and “excellent” in ease, while the support material was “good” in quality, “average” clarity, and “average” quantity.

To contrast the performance and learning of the students, the decision was made to average the final grade obtained in the course. The students who used the simulator were considered as group one, and those who did not use it as group two.

Tabla 4. Ponderación numérica de acuerdo con la posición en la barra deslizable

Posición en la barra	Evaluar simulador		Evaluar material de apoyo		
	Ayuda	Facilidad	Calidad	Claridad	Cantidad
$0 \leq x \leq 20$	Mala	Muy difícil	Mala	Nada claro	Muy poco
$20 < x \leq 40$	Insuficiente	Difícil	Insuficiente	Poco claro	Poco
$40 < x \leq 60$	Promedio	Regular	Promedio	Claro	Suficiente
$60 < x \leq 80$	Buena	Fácil	Buena	Muy claro	Mucho
$80 < x \leq 100$	Excelente	Muy fácil	Excelente	Clarísimo	Demasiado

Fuente: Elaboración propia

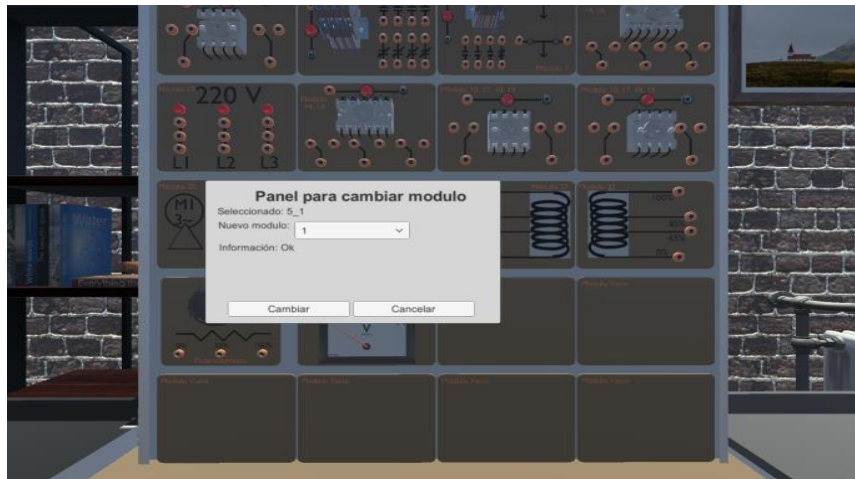
In group one, the final average score of the students was 95.6, while in group two it was 84.75, which shows a favorable trend for this new tool.

Features

Virtual laboratory functionalities

Here are some of the main features of the simulator; for example, it is possible to customize the workspace with the power and control modules needed to design a system (figure 3).

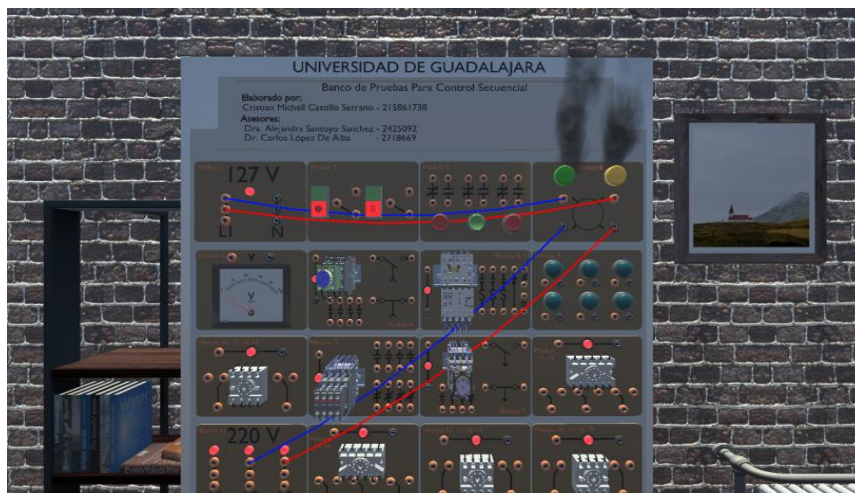
Figura 3. Personalización del espacio de trabajo



Fuente: Elaboración propia

The simulator is capable of detecting and reporting errors in the system in real time, and returning feedback to the user (figure 4).

Figura 4. Ejemplo de corto circuito por interacción de varias fases



Fuente: Elaboración propia

Connections and relationships between components can be customized for proper cable management (Figure 5).

Figura 5. Ejemplo de personalización de conexiones



Fuente: Elaboración propia

It is possible to monitor in real time the variation of each one of the components of the system and to inspect its operating parameters (figure 6).

Figura 6. Ejemplo de monitorización de un motor eléctrico trifásico



Fuente: Elaboración propia

In addition, force and control systems can be created through the interaction and use of various sequential control components (Figure 7).

Figura 7. Ejemplo de sistema con diversos componentes de control y fuerza



Fuente: Elaboración propia

The simulator has a complete options panel that allows saving and loading previous simulations, managing the quality and values of the graphic, visual and operational aspects, among others (figure 8).

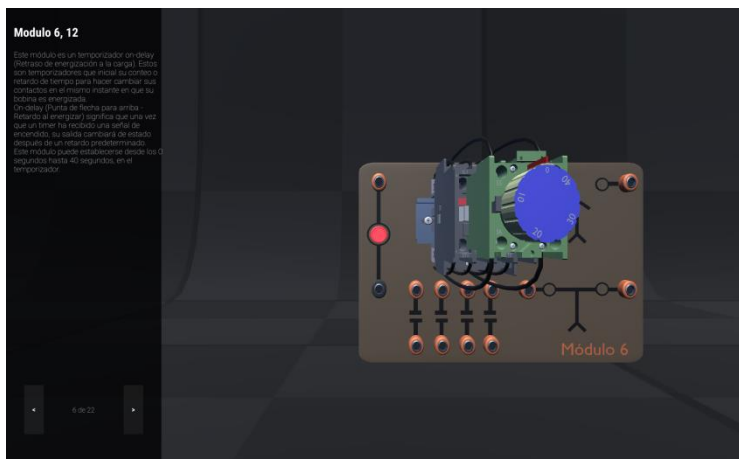
Figura 8. Opciones del menú de pausa



Fuente: Elaboración propia

It also has a section to learn through specific information the operating parameters, characteristics, and operation of each of the models available in the simulator (figure 9).

Figura 9. Ejemplo de material de apoyo

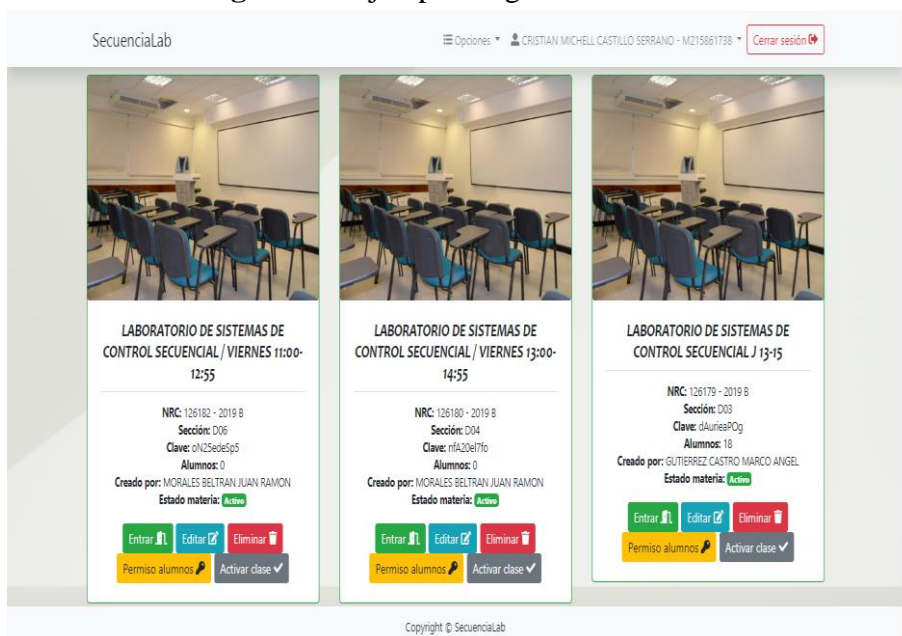


Fuente: Elaboración propia

Learning platform functionalities

Here are some of the main functionalities of the learning platform; for example, it is possible to complete the creation and management of classes by teachers (figure 10).

Figura 10. Ejemplo de gestión de clases



Fuente: Elaboración propia

It is possible to create backup copies of the information stored in the system (figure 11).

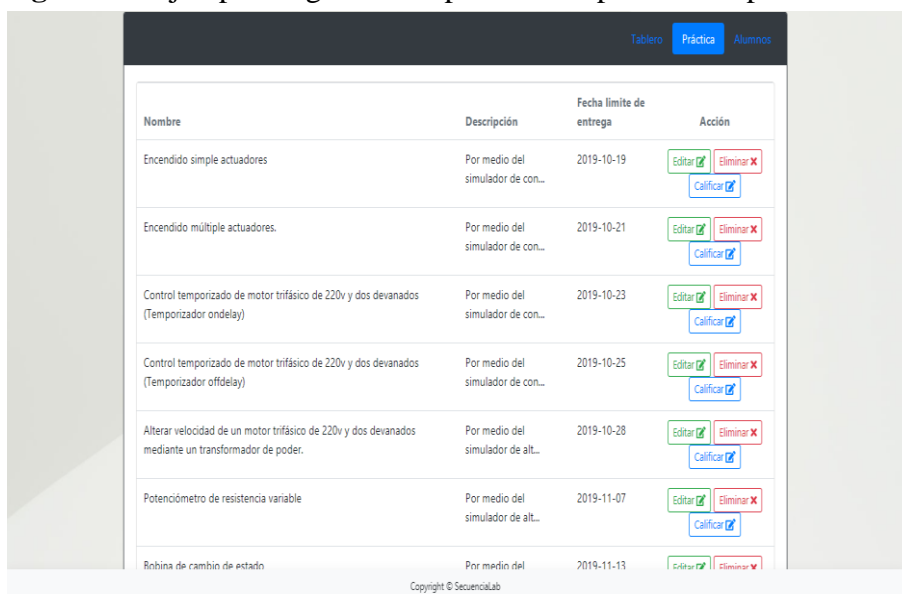
Figura 11. Muestra de respaldos del sistema



Fuente: Elaboración propia

Additionally, deliverables can be created and managed for students (Figure 12).

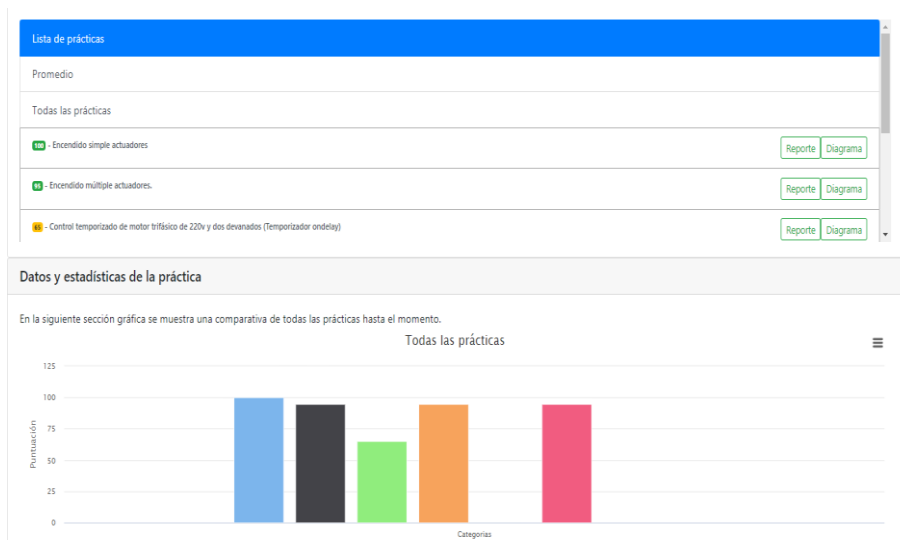
Figura 12. Ejemplo de gestión de prácticas/experimentos para alumnos



Fuente: Elaboración propia

Likewise, it is possible to monitor user performance based on statistical information (figure 13).

Figura 13. Ejemplo de monitorización de estudiantes



Fuente: Elaboración propia

Likewise, it is possible to generate performance reports and qualifications (figure 14).

Figura 14. Ejemplo de reporte de calificaciones

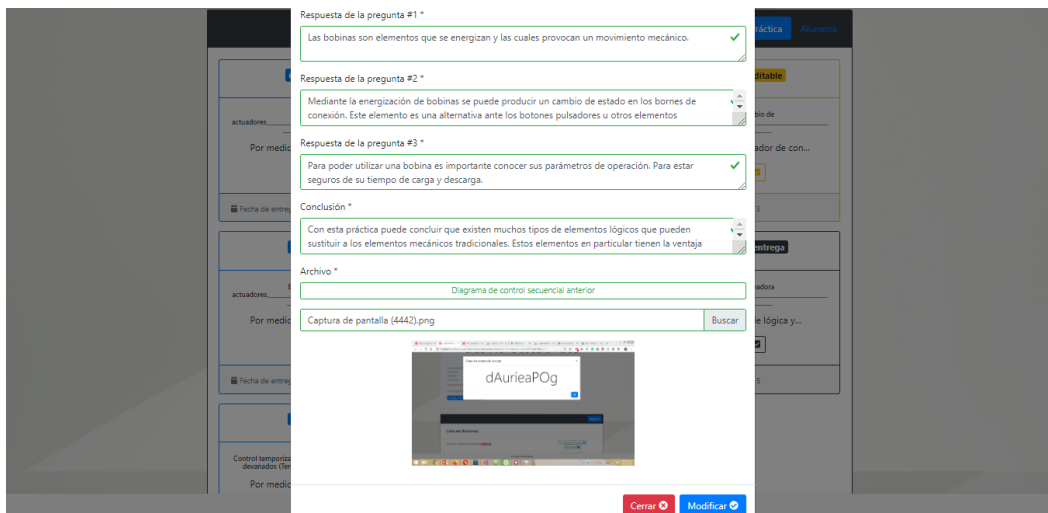
Reporte de calificaciones de clase

Datos de la clase										
Clave de acceso	dAurieaPOj		Nombre materia			LABORATORIO DE SISTEMAS DE CONTROL SECUENCIAL				
NRC	126179		Sección			D03				
Nombre Clase	LABORATORIO DE SISTEMAS DE CONTROL SECUENCIAL J 13-15					Aula	DEDS			
Año	2019			Ciclo	B					
Relación de calificaciones										
Nombre alumno	Encendido simple actuadores	Encendido múltiple actuadores	Control temporizado de motor trifásico de 220v y dos devanados (Temporizador ondelay)	Control temporizado de motor trifásico de 220v y dos devanados (Temporizador offdelay)	Alterar velocidad de un motor trifásico de 220v y dos devanados mediante un transformador de poder.	Potenciómetro de resistencia variable	Bobina de cambio de estado	Movimiento lavadora motor	Bomba de agua	Promedio
A211584799 - ARIANA MOLINERO, STEVEN AUGUSTO	70	85	90	77	90	Sin calificación	88	Sin calificación	Sin calificación	83.3333
A215861739 - CASTILLO SERRANO, CRISTIAN MICHELL	100	95	65	95	0	95	Sin calificación	0	Sin calificación	64.2857
A215861738 - CASTILLO SERRANO, CRISTIAN MICHELL	0	0	0	0	0	0	Sin calificación	Sin calificación	Sin calificación	0
A211576189 - HERNANDEZ HERNANDEZ, JOSÉ MARIA	85	95	67	95	Sin calificación	40	55	Sin calificación	Sin calificación	72.8333
A211077689 - HERNANDEZ, PEREZ, MARTIN	0	100	60	95	85	Sin calificación	Sin calificación	Sin calificación	Sin calificación	68
A211735592 - JASSO ABURTO, ALDAMIR YAREL	Sin calificación	Sin calificación	Sin calificación	Sin calificación	Sin calificación	Sin calificación	Sin calificación	Sin calificación	Sin calificación	Sin promedio

Fuente: Elaboración propia

It is also possible to deliver activities / practices by students (figure 15).

Figura 15. Formulario para entrega de prácticas



Respuesta de la pregunta #1 *

Las bobinas son elementos que se energizan y las cuales provocan un movimiento mecánico. ✓

Respuesta de la pregunta #2 *

Mediante la energización de bobinas se puede producir un cambio de estado en los bornes de conexión. Este elemento es una alternativa ante los botones pulsadores u otros elementos

Respuesta de la pregunta #3 *

Para poder utilizar una bobina es importante conocer sus parámetros de operación. Para estar seguros de su tiempo de carga y descarga. ✓

Conclusión *

Con esta práctica puede concluir que existen muchos tipos de elementos lógicos que pueden sustituir a los elementos mecánicos tradicionales. Estos elementos en particular tienen la ventaja

Archivo *

Diagrama de control secuencial anterior

Captura de pantalla (4442).png

Fuente: Elaboración propia

Discussion

One of the main disadvantages of conventional laboratories is the lack of availability of equipment, which usually occurs due to permanent damage, lack of maintenance, budget shortages, etc., which has forced different institutions to use virtual laboratories.

In this sense, and to try to solve this problem, it was decided to develop the virtual laboratory simulator SequenceLab, which allowed a group of students to carry out virtual practices / experiments on certain equipment in the sequential control laboratory (figures 3-12) Through a simulator that implemented Unity version 2019.1.5f, Blender 2018, Adobe Photoshop and Adobe Illustrator.

In addition, a learning platform was used to help teachers and students keep track of practices and classes (Figures 13-15). This allowed the teachers to monitor the practices carried out and the number of attempts that each student required to obtain the desired result. On the other hand, the students were allowed to practice at any time and without having to have physical contact with the equipment in the sequential control laboratory.

To evaluate the effectiveness of this technological tool during the school period, a group of students was chosen to complement the curriculum and resources of a course taught in a traditional way. Subsequently, they were asked to carry out an evaluation of the simulator and the support material.

In order to avoid that the students were predisposed or that a possible bias was generated in the results, a sliding bar was offered in the evaluation, which served to fulfill the activity without showing the result as a numerical value. The data obtained shows that the majority of the students who took the evaluation agreed with the use of the simulator in an interactive way.

On the other hand, to evaluate the performance and learning of the students, it was decided to contrast the final grade average obtained by the students who used the simulator against those who did not use it. In this regard, it was found that the first students obtained an average grade of 10.85 points more than those who did not use it. This shows that the simulator significantly improves students' learning, as it allows them to repeat the experiments as many times as necessary, which ultimately helps to understand the topics of the subject (Achuthan et al., 2011).

On the other hand, it should be noted that one of the main obstacles to efficiently measure student performance and learning using artificial intelligence tools is the need to use research questions focused on these two criteria, since in this way it can be reduced the bias caused by traditional methods. This, in addition, allows to quantify other relevant factors, and not only the final grade of the student.

Likewise, it is possible to work on the construction of learning activities and exercises that incorporate other components, as well as the customization of the operating parameters of the practices / experiments to be carried out. In addition, to implement collaborative learning, the connectivity capabilities of the software can be improved.

Conclusions and future work

In this work the design of an educational software (SequenceLab: virtual laboratory) structured in two components was described. The first is a simulator that works as a desktop application for the creation, design and testing of elements for the Sequential Control Systems subject, in order to reinforce the education of undergraduate or higher students related to the Engineering career. Electrical Mechanics.

The approach of this simulator allows students and teachers to have a mechanism to create and experience sequential control systems in a virtual environment. In this way, an attempt is made to overcome the problems of using physical systems, that is, the lack of availability

of physical equipment, the wear and tear of the components, the travel time to get to the laboratory, the lack of material, etc.

The second component is a learning platform for the control of practices and classes, which allows teachers not only to supervise in more detail their subjects and the performance of their students, but also to comply with the specific operational requirements requested by the university. (evaluation reports, group reports, class evaluations). Students, for their part, can easily answer the practices of their subject and keep a detailed control of their grades. The platform helps to keep a better record of the subjects and streamline the administrative processes related to their delivery. Through this, it seeks to complement and promote the education of students through the use of information technologies.

On the other hand, the results of the feedback survey to evaluate the simulator and the support material allow monitoring of the virtual laboratory, since they indicate the elements that need to be improved.

As future work, the components should be extended, the operating parameters customized and tests carried out in the next school year on learning and effectiveness when using the application. Additionally, the software's connectivity capabilities can be enhanced to enable multi-user collaboration from different devices.

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