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ORIGINAL

Design and implementation of a control system in an autoclave as an educational tool for biomedical engineering students

Diseño e implementación de un sistema de control en autoclave como herramienta educativa para estudiantes de ingeniería biomédica

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ABSTRACT

This study focused on the design and implementation of an automated control system for a Pelton & Crane model MC autoclave, with the aim of transforming it into a modern and didactic tool for Biomedical Engineering students. The equipment was structurally redesigned, and sensors, actuators, and a graphical user interface were integrated to illustrate the internal operation of the sterilizer in real time. The educational strategy was structured into four sequential stages: (1) identification of components and maintenance practices, (2) animated visualization of the sterilization cycle, (3) demonstration of the water treatment system, and (4) diagnosis of common faults. To validate the academic impact, knowledge surveys were applied before and after the practical experience. The results showed a significant improvement in students' understanding of sterilization principles and autoclave maintenance. The modified device achieved standard sterilization conditions (121 °C, 205 kPa), and its educational use led to a 94 % increase in average student performance on evaluations. Overall, the educational autoclave proved to be an effective tool for reinforcing hands-on learning and enhancing the training of future biomedical engineers.

Keywords: Educational Autoclave; Sterilization; Didactic Tool; Biomedical Engineering; Automated Control.

RESUMEN

Este estudio se centró en el diseño e implementación de un sistema de control automatizado para una autoclave Pelton & Crane modelo MC, con el propósito de convertirla en una herramienta moderna y didáctica para estudiantes de Ingeniería Biomédica. Se rediseñó estructuralmente el equipo y se integraron sensores, actuadores y una interfaz gráfica de usuario para ilustrar en tiempo real el funcionamiento interno del esterilizador. La estrategia educativa se estructuró en cuatro etapas secuenciales: (1) identificación de componentes y prácticas de mantenimiento, (2) visualización animada del ciclo de esterilización, (3) demostración del sistema de tratamiento de agua, y (4) diagnóstico de fallas comunes. Para validar el impacto académico, se aplicaron encuestas de conocimientos antes y después de la experiencia práctica. Los resultados mostraron una mejora significativa en la comprensión de los principios de esterilización y mantenimiento de autoclaves por parte de los estudiantes. El dispositivo modificado logró condiciones de esterilización estándar (121 °C, 205 Kpa) y su uso didáctico incrementó en un 94 % el desempeño promedio en las evaluaciones de los alumnos. En conjunto, la autoclave educativa demostró ser una herramienta eficaz para reforzar el aprendizaje práctico y potenciar la formación de futuros ingenieros biomédicos.

Palabras clave: Autoclave Educativa; Esterilización; Herramienta Didáctica; Ingeniería Biomédica; Control Automatizado.

INTRODUCTION

Steam sterilization is one of the most widely used methods in hospitals for eliminating pathogenic microorganisms in medical materials. This process, based on the application of saturated steam at high temperature and pressure, ensures effective sterilization when controlled conditions of 121 °C and 205 kPa are reached for a minimum of 15 minutes. Understanding this process requires knowledge not only of microbiology and thermodynamics, but also of pressurized system mechanics, automatic control, and international standards such as EN 13060 (small-capacity steam sterilizers) and AAMI ST79 (for water quality and validation procedures).

In the context of biomedical engineering education, mastery of autoclave operation and maintenance is a fundamental skill. However, in most university programs, the teaching of medical technologies is limited to theoretical classes or practical classes limited to observation, mainly due to the operational complexity and risks inherent in handling actual autoclaves in operation. This lack of contact with the equipment during the training stage results in graduates with little practical experience, difficulty in identifying technical faults, and dependence on external support for preventive or corrective maintenance tasks.

Several authors emphasize the importance of supplementing theoretical teaching with practical and interactive tools to improve understanding of biomedical technologies.[1] In the case of sterilizers, inadequate training can lead to recurring failures and excessive dependence on specialized personnel to resolve them. Therefore, there is a need to develop educational platforms that allow students to explore the inner workings of complex equipment such as autoclaves in a safe and controlled manner. Previous studies have reported low levels of knowledge about sterilization processes among healthcare personnel, highlighting training gaps that could be addressed through more practical educational strategies.

In line with this, this article describes the design, implementation, and validation of a modernized educational autoclave, based on decommissioned clinical equipment, adapted for use as an interactive teaching tool. The proposal includes a control system based on Raspberry Pi, precision sensors, a graphical user interface developed in PyQt5, and a demonstration water treatment plant. The pedagogical structure is divided into four sequential modules that guide students from the recognition of internal components to the resolution of simulated faults. Technical results of operation, sterilization tests, and quantitative data on the educational impact on biomedical engineering students are presented.

Figure 1. Shows the final teaching equipment, the result of the modernization process. Pelton et al. autoclave modified as a teaching tool, showing the interior of the sterilization chamber and components of the new control system (sensors, wiring, and actuators)

METHOD

The project was developed based on a Pelton & Crane MC tabletop autoclave that was previously out of service. The procedures followed in the redesign of the equipment, the development of the control system and educational interface, and the educational validation with students are described below, in accordance with an experimental approach in the laboratory. All stages were documented following a logical sequence of implementation.

Mechanical and electrical redesign of the autoclave

It began with a thorough inspection of the original sterilizer to identify components, malfunctions, and opportunities for modification for educational use. Corrective maintenance was performed, including the maintenance or replacement of damaged components and the optimization of the autoclave's piping circuit to facilitate visual understanding. Electrical, mechanical, and software safety devices were also incorporated. The external casing of the equipment was adapted to expose internal elements of interest and achieve a balance between the visibility of the components and the safe operation of the autoclave by students. In addition, a front control panel with indicator lights was installed, with an adequate and easily accessible layout for measurement, verification, and maintenance activities. In summary, the autoclave was reconditioned to serve as an educational platform, maintaining its sterilization functionality but adding elements that facilitate its handling and understanding in an academic environment.

Educational graphical interface

An application with a graphical user interface (GUI) was implemented using the PyQt5 library on the Raspberry Pi Linux environment. The GUI was displayed on a 10-inch LCD touch screen attached to the equipment. The interface design followed usability guidelines for learning environments, organizing the information into clearly identified teaching modules. In particular, four main windows were defined, corresponding to the four stages of the planned educational sequence. Each window features specific graphics, animations, and interactive controls, facilitating guided exploration by the student:

- **First stage (Components and maintenance):** the interface displays all the system components individually (figure 2). When each component is moved on the screen, the system displays a brief description of its function, its importance within the whole, and associated preventive or corrective maintenance recommendations. In addition, the actuators (e.g., solenoid valves, heating elements) have virtual On/Off switches that allow them to be activated momentarily in isolation, so that the student can observe their individual operation and immediate effect on the system (e.g., see the heating elements working and measure their power consumption or see the change in state of a solenoid valve). This initial stage seeks to familiarize the user with the identification of each part of the autoclave and lay the groundwork for subsequent stages; the student develops recognition skills and learns basic procedures such as checking the status of a gasket, checking the status of a sensor, or performing maintenance work on a solenoid valve, relying on practical guides provided as supplementary material.

Figure 2. Example of First Stage windows

- **Second stage (Sterilization process):** in this module, the screen displays an animated synoptic diagram that represents the complete sterilization cycle inside the autoclave in real time (figure 3). Animations are included for the filling, heating, homogenization, sterilization (exposure), depressurization, and drying/cooling phases, synchronized with the actual operation of the equipment. Visual indicators

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show the status of each sensor and actuator during the cycle (e.g., the discharge valve opening during the depressurization phase, the heating element on during heating, etc.). In addition, dynamic pressure and temperature graphs can be viewed in a sub-window, allowing the thermodynamic curves of the process to be followed live. The student interacts by starting the cycle from the GUI, after which they observe its development with the support of explanatory texts and s that appear at each stage, describing what is happening and why. This second stage links the previously learned components with their functional role, helping to understand how the different parts interact during normal autoclave operation.

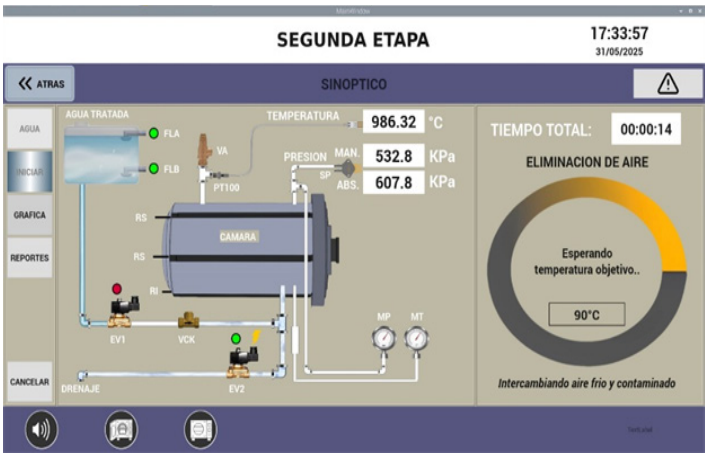

Figure 3. Second stage window

- **Third stage (Water treatment):** a water treatment plant connected to the autoclave was integrated into the system to emphasize the importance of water quality in the sterilization process. In the interface, a dedicated window schematically illustrates the stages of purification: pre-filtration, softening, reverse osmosis, and storage (figure 4). Through demonstrative images, students can follow the path of water from an initial supply tank to its treatment. Each sub-stage presents information on its function (e.g., particle removal, hardness reduction, salt and microorganism removal) and its importance in preventing damage to the autoclave (scaling, corrosion) and ensuring effective sterilization. This section is aligned with international standards (such as AAMI ST79 and EN 13060 recommendations on water purity for sterilization) and provides reference data on the quality of the water obtained. The inclusion of this module reinforces interdisciplinary concepts in biomedical engineering related to the preservation of medical equipment.

Figure 4. Third stage window

- **Fourth stage (Fault diagnosis):** in the final stage, the teaching tool presents scenarios of frequent faults in steam autoclaves, simulated in the interface (figure 5). Students can navigate between different common malfunction cases (e.g., heater failure, valve leak, faulty temperature sensor, etc.) using forward/backward controls. For each failure, students must follow a structured list of tests and checks to identify the root cause. These diagnostic guidelines are based on actual maintenance protocols recommended by autoclave manufacturers, adapted to the educational level. The educational objective is to consolidate all the knowledge acquired in the previous stages by applying it to a real-life problem-solving situation. In this way, students develop critical thinking skills and maintenance methodology, which are essential for their future professional practice. Once the diagnosis has been completed in the interface, the appropriate corrective measures are discussed with the instructor, encouraging analysis and technical discussion.

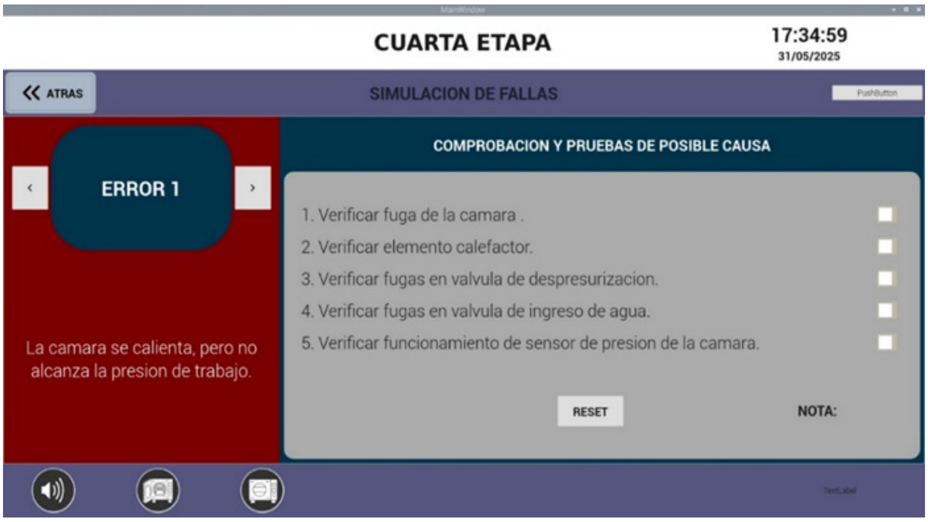

Figure 5. Fourth stage window

It is worth mentioning that all the windows and functions of the graphical interface were programmed in PyQt5, ensuring visual consistency and ease of use that proved to be intuitive, allowing students with little previous experience to navigate the four stages without significant difficulty.

Functional and didactic validation

Once implementation was complete, the autoclave was checked to ensure it was functioning correctly under automated control. Multiple test sterilization cycles were carried out with simulated loads, monitoring the recorded temperature and pressure curves. The results showed that, after adjustments to the air removal sequence and the PWM controller parameters, the system reached a stable sterilization plateau of 121 ± 1 °C during the required time (15 min), maintaining the pressure in accordance with saturated steam (~205 kPa absolute) (figure 6). These values comply with the recommendations of the EN13060 standard for class N autoclaves. To confirm the effectiveness of sterilization, class 4 chemical indicators were placed at different points in the chamber during complete cycles. In all cases, the correct color change was observed in the indicators, demonstrating that the necessary conditions of time, temperature, and saturated steam were achieved. This practical validation ensured that the equipment fully complies with its clinical sterilization function, but with an educational focus.

Figure 6. Final graph of the sterilization cycle

Automated control system

In parallel with the physical refurbishment, an electronic system based on a Raspberry Pi 4 with interface

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circuits for sensors and actuators was designed. A custom control board with signal conditioners and power drivers was developed to control the autoclave components. The system includes: a PT100 temperature sensor with A/D converter, piezoresistive pressure sensor, water level sensors, heating resistors, and solenoid valves for inlet and purge. The control executes a programmed algorithm that regulates temperature and pressure according to the sterilization cycle, using PWM modulation logic in accordance with EN 13060. An air removal routine was incorporated at the beginning of the cycle to ensure homogeneous steam penetration and distribution. Safety alarms (for overpressure, overtemperature, water shortage, or sensor failures) were also implemented, which activate visual and audible alerts, stopping the cycle if necessary. All process data and events are stored in an SQLite database for academic monitoring and maintenance.

Finally, to evaluate the educational usefulness of the autoclave, a pilot study was conducted with biomedical engineering students. Before the educational intervention, a written diagnostic test consisting of 10 multiple-choice questions was administered to 30 seventh-semester students enrolled in the course "Medical Instrumentation II." This course includes theoretical content on autoclaves and water treatment systems, so the exam sought to measure the prior knowledge acquired through traditional methods. The questions addressed topics such as operating principles, safety measures, and basic concepts about water used in sterilization. The results showed poor performance: only 35 % of answers were correct on average, and some questions had up to a 90 % error rate, revealing significant weaknesses in theoretical learning.

Subsequently, a practical training session was held with 10 students in the UMA research center laboratory (figure 7), following the four defined teaching stages: (1) identification and maintenance of real components, (2) observation of a sterilization cycle with animated visual support, (3) demonstration of the water treatment system, and (4) analysis of simulated failures for diagnosis. During the practical session, the students interacted directly with the equipment: they activated solenoid valves, measured electrical variables with multimeters, and monitored temperature and pressure in real time. The activity was guided by an instructor, who promoted learning through questions and constant feedback. At the end of the training (approximately 2 hours long), a second diagnostic survey with questions similar to the initial one was administered to measure the increase in learning achieved.

Figure 7. Student participation in practical training using the teaching tool

RESULTS

Performance of the implemented system

The modified autoclave responded satisfactorily in functional tests. Automatic sterilization cycles were completed in compliance with the required parameters. figure 1 illustrates the final appearance of the system, where the modifications made can be seen. During testing, after correcting sealing and control problems, a temperature of 121°C was reached and maintained for 15 minutes in the sterilization phase, with a stable pressure of ~130 Kpa manometric, in accordance with saturated steam conditions. The graph of the last test showed a stable plateau with no abrupt pressure drops at the end of the cycle, indicating good air removal and adequate power control during heating. The chemical indicators used turned completely after the cycle, validating the effectiveness of the process. These results confirm that the integration of the new control system did not compromise the clinical functionality of the equipment, but rather optimized it. Likewise, the data acquisition system in the Raspberry Pi proved to be reliable: reports were generated for each cycle with their respective temperature/pressure curves, which can be used for further analysis in class.

As for the performance of the educational interface, during the practical session, students navigated the four stages of the interface without difficulty. The tactile response was fluid, and the animations were correctly synchronized with the actual process. Of particular note was the interest in the graphical visualization of the sterilization cycle, which facilitated theoretical and practical understanding. They also appreciated the ability to manually control internal components, which allowed for safe interaction with the system. No software failures or disconnections were recorded, demonstrating the stability of the hardware-software integration.

Impact on student learning: Comparison of the initial and final assessment results revealed a substantial increase in the students' level of knowledge after interacting with the teaching tool. In the pre-training diagnostic test, the average score was 35/100, reflecting a low mastery of concepts related to autoclaves. In contrast, in the post-training test, the average rose to 68/100 points. This difference represents an improvement of approximately 94 % over the students' initial performance. In addition to the increase in the average score, the percentage of correct answers increased across all 10 questions in the survey. Initially, about 65 % of the total responses were incorrect; after the intervention, the error rate decreased to 32 %. In particular, we noted significant progress in items addressing practical issues: for example, the question on the air purge procedure in the autoclave went from 7 % correct before training to 80 % correct after; the identification of the component responsible for removing water hardness (softener) rose from 20 % to 90 % correct answers; and so on for the other topics. This indicates that direct experience with the educational autoclave reinforced both general and specific knowledge, especially those that are difficult to consolidate with theoretical classes alone. It should be noted that even safety concepts, such as the response to overpressure, were better understood after the practical session (evidenced by an increase from 50 % to 100 % correct answers to the corresponding question). All the students surveyed informally expressed that they found the activity very useful for visualizing and reinforcing what they had learned in the classroom, and several suggested that this type of tool be implemented in more subjects in the degree program. Although the sample size for the practical evaluation was small (10 students), the quantitative results obtained provide a clear indication of the pedagogical effectiveness of the autoclave designed.

DISCUSSION

The findings clearly show that the use of the adapted autoclave as a teaching tool improved students' understanding and retention of knowledge. The dramatic difference between the scores on the initial theoretical assessment and those after the practical session highlights the limitations of the traditional teaching approach when it is not accompanied by sufficient practical experience. Before the intervention, the students had fragmented and incomplete notions about the actual operation of a sterilizer, despite having studied the relevant content in class. This is consistent with situations reported in the literature, where simple theoretical exposure to complex equipment does not guarantee mastery by future professionals.[2] After interacting with the educational autoclave, students demonstrated not only better recall of the concepts, but also understanding them in context, being able to relate causes and effects within the system (for example, how a failure in the water supply impacts steam generation). This type of holistic understanding is a central goal in engineering education, as it prepares students to solve real-world problems beyond textbook exercises.

In pedagogical terms, the strategy of dividing learning into four sequential stages proved successful. During the first stage, active learning through exploration of components and performance of maintenance tasks generated a tangible foundation on which students built more abstract knowledge in later stages. This aligns with experiential learning theories, which postulate that direct manipulation of objects of study facilitates the formation of more robust cognitive schemas. The second stage, with the animation of the internal process, allowed students to dynamically visualize phenomena that would otherwise be invisible (such as steam distribution and the action of automatic controls). This visualization, supported by real-time data, acted as a bridge between thermodynamic theory and clinical practice, confirming the usefulness of interactive simulations linked to real physical processes.[3] For its part, the inclusion of the third stage relating to water treatment added an interdisciplinary component that enriches the training: typically, curricula may overlook details about external processes that go hand in hand with sterilization equipment, but our experience shows that by emphasizing this aspect, students better understood why an autoclave can fail due to poor water quality and how to prevent it. This is highly relevant, as studies indicate that mineral buildup from hard water is one of the common causes of breakdowns in hospital autoclaves.[4] Thus, exposing students to the operation of a real purification system not only reinforces their knowledge of bioengineering , but also encourages a proactive attitude toward preventive maintenance, which will be valuable in their future work performance.

The fourth stage of fault diagnosis promoted the development of critical thinking and problem-solving skills, which are cross-cutting competencies in engineering. By simulating breakdowns and guiding students in their resolution, the learning process shifted from passive to active, requiring students to apply their prior knowledge in an integrated manner. The positive reception of this dynamic suggests that incorporating problem-solving scenarios into medical technology education is highly beneficial. In line with this, authors such as Çengel et al.[5] have highlighted that analyzing practical cases and experimenting with "what if..." scenarios strengthens the understanding of applied thermal engineering principles, rather than just memorizing nominal values. In our case, students not only correctly identified defective components in the simulations, but also discussed in groups the measures to correct the problems. This collaborative and reflective aspect is an indicator of deep learning, as participants were able to articulate and communicate technical reasoning, something that is difficult to achieve with traditional theoretical assessments.[6]

Another point to highlight in the discussion is the viability and sustainability of this type of project. The transformation of obsolete equipment into an active educational resource demonstrates an efficient strategy for leveraging institutional resources. With a relatively modest investment (funded in this case by the university) in electronic components, sensors, and reused materials, a valuable teaching device was recovered. This opens the door for other institutions to consider implementing similar initiatives, as university laboratories often have out-of-service equipment that could be adapted for academic purposes. In addition, implementation on open platforms (Raspberry Pi, Python/PyQt) facilitates reproducibility and future improvements without relying on costly proprietary technologies. From an academic management perspective, incorporating the educational autoclave into the practical curriculum of the degree program can significantly improve graduate competencies related to healthcare technology management. Biomedical engineers trained with these types of tools will be better prepared to face real challenges in hospitals, such as calibrating equipment, training clinical staff in the correct use of devices, or implementing preventive maintenance plans.[7]

Finally, it is pertinent to briefly compare our proposal with other teaching methodologies in biomedical engineering. In recent years, the use of virtual simulators and remote laboratories for teaching medical devices has increased. While these tools are valuable for expanding access (for example, when equipment is not physically available), they have limitations in terms of sensory experience and tangible interaction with systems. The educational autoclave combines the best of both worlds: it is a real system, with all the variables and unpredictabilities of physical equipment, but controlled in such a way as to provide safety and a structured learning environment. This philosophy of "learning in a real environment" is aligned with STEM education trends that promote more active and participatory laboratory environments. The results obtained support the idea that learning by doing in the field of biomedical engineering increases student motivation and knowledge retention. Likewise, the documentation generated (user manual, practice guides, cycle database) remains as a permanent resource for future generations, ensuring a lasting impact beyond the pilot group.[8]

A limitation of the study is that the formal evaluation was conducted with a small number of students. It would be advisable in future work to expand the sample size in order to quantify the difference in learning with greater statistical rigor. Additional metrics could also be explored, such as medium-term monitoring of knowledge retention or student performance in related professional practices. However, even with the limitations mentioned, the current findings constitute positive evidence of the educational benefit of the teaching autoclave.[9]

CONCLUSIONS

An educational autoclave was successfully implemented, providing biomedical engineering students with a practical, safe, and interactive learning experience on the sterilization and maintenance processes of medical equipment. The developed system integrates reused hardware with modern control technology (Raspberry Pi, sensors, actuators) and an intuitive graphical interface, transforming a conventional sterilizer into a powerful teaching tool. The four-stage teaching sequence allowed students to progressively understand everything from component identification to troubleshooting, consolidating a comprehensive understanding of how the autoclave and its auxiliary water treatment system work.

The academic results associated with the use of the tool were outstanding: participants demonstrated an approximate 94 % increase in their performance on knowledge assessments, demonstrating the effectiveness of the practical approach in reinforcing theoretical and practical concepts. The experience also increased the motivation and interest of the students, who were able to link the class content to the operational reality of critical biomedical equipment. It is concluded that the incorporation of this type of educational platform in the training of biomedical engineers strengthens essential skills, such as systems analysis, critical thinking, and preventive maintenance skills, which are difficult to achieve through traditional, exclusively theoretical methods.

In engineering terms, the project demonstrated the feasibility of technologically upgrading disused medical equipment for educational purposes, complying with operating standards without compromising safety. The system managed to maintain critical sterilization parameters: temperature 121°C ±1°C, gauge pressure 130 kPa ± 7 kPa, and an exposure time of 15 minutes, which was validated in multiple tests with class 4 chemical indicators that confirmed the effectiveness of the sterilization process. The modified Pelton & Crane autoclave not only regained its operability, but now serves as a permanent training bench in the university laboratory. This approach is replicable to other biomedical devices, promoting educational innovation, institutional sustainability, and the strengthening of technical skills in the training of biomedical engineers.

Finally, it is recommended to continue evaluating and improving the tool: incorporating new functionalities (e.g., interactive evaluation modules, more failure scenarios), as well as officially integrating the teaching autoclave into the degree program's curriculum. Similarly, sharing this experience with the academic community may encourage the creation of a network of teaching laboratories in biomedical engineering at the national level, raising the level of practical preparation of future professionals. In conclusion, the project had a positive impact on academic training, demonstrating that practice-based learning with real equipment, supported by modern interfaces, is an effective way to bridge the gap between theory and practice in biomedical engineering.

REFERENCES

1. Muñoz EJ. ¿Cómo funciona una autoclave de vapor?. Equipamiento JM; 2023 Oct 24. Disponible en: https://equipamientojm.com/todo-sobre-autoclaves/como-funciona-un-autoclave/

2. Robilotti S, Couso A. Procesos de esterilización. En: Compendio de Ingeniería Biomédica. Codeinep; 2011. p. 45-60.

3. Garrido N. Manual básico del uso de autoclaves. Tuttnauer; 2015. Disponible en: https://tuttnauer.com/blog/esterilizacion-por-autoclave/que-es-un-autoclave

4. Interempresas. Tratamiento de agua para calderas. 2021. Disponible en: https://www.interempresas.net/Agua/Articulos/356671-Tratamiento-de-agua-para-calderas.html

5. Çengel YA, Boles MA. Thermodynamics: An Engineering Approach. 8ª ed. McGraw-Hill Education; 2015.

6. Acosta J, Andrade R. Manual de esterilización para centros de salud. Organización Panamericana de la Salud; 2008. Disponible en: https://www.paho.org/es/documentos/manual-esterilizacion-para-centros-salud-2008

7. European Committee for Standardization. EN 13060: Small steam sterilizers. Brussels, Belgium: CEN; 2004.

8. Lenntech. El agua en la central de esterilización. 2024. Disponible en: https://www.lenntech.es/aplicaciones/ultrapura/conductividad/conductividad-agua.htm

9. Silvestre C, Fagoaga L, Garciandía MJ, Lanzeta I, Mateo MC, Zapata MC. Esterilización. An Sist Sanit Navar. 2000;23:95-103.

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CONFLICT OF INTEREST

None.

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