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ANALYSIS OF NEEDS AND OPPORTUNITIES FOR CREATING AN INTERDISCIPLINARY LABORATORY TO SUPPORT IN AUTOMATION AND SYSTEMS ENGINEERING COURSES

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Abstract. *The present work addresses the analysis of needs and opportunities for creating an interdisciplinary laboratory to support the development of competencies in education in Automation and Systems Engineering. Within the scope of the New National Curriculum Guidelines for the Undergraduate Course in Engineering, published in 2019, there are points that highlight the need to develop skills in graduates and the use of active methodologies during the teaching and learning process. In view of this, we seek to understand the needs and opportunities for structuring a didactic laboratory of industrial automation as an educational resource for engineering courses and companies that wish to apply training to their employees. In the process of solving problems and developing innovative projects, the needs analysis is a step that belongs to the informational phase and aims to identify the customer's requirements and transform them into design requirements. As a methodology, the House of Quality was used, which consists of a systematic matrix that lists the fields of consumer attributes, engineering characteristics, bodywork and roof. Consumer attributes present the customer's desires in a systematic way, such desires are often mentioned crudely and need to be refined for inclusion in the House of Quality. The engineering characteristics are technical attributes related to the automation laboratory under development, such points are defined with units of measurement and the need for maximization or minimization in the automation laboratory project is also indicated. In many cases, a preliminary design is selected as the starting point for obtaining these characteristics. The body of the House os Quality is a matrix that relates engineering characteristics and consumer attributes, through notes that express the level of relationship between these two points, that is, how much each engineering characteristic impacts, positively or negatively, the attributes of the product. consumer. The House of Quality roof expresses the relationship between engineering features, which can be positive, negative, or neutral. A survey of consumer attributes about the automation laboratory for engineering teaching was carried out in the literature related to engineering teaching, the specific engineering characteristics of the theme were defined, and from the House of Quality, the project requirements that guided the projects were obtained. functional aspects of infrastructure, personnel, operational processes and indicators for measuring the skills developed in the didactic laboratory.*

Keywords: *engineering education, interdisciplinary laboratory of systems automation, quality Function Deployment matrix.*

1. INTRODUCTION

The professional role of an Engineer is challenging because it demands the application of technical and scientific knowledge in solving highly complex societal problems. In this regard, the education of engineering professionals should encompass the integration of theoretical and practical content in a balanced manner across various settings, one of which is educational laboratories. Thus, through educational laboratories, the aim is to secure suitable spaces for the execution, analysis, and reflection of processes in various engineering domains.

In industrial sectors, it is increasingly necessary for engineers to possess interdisciplinary knowledge that is aligned with a diverse set of competencies. These competencies encompass the ability to formulate and conceive engineering solutions, analyze and comprehend physical and chemical phenomena, design, project, and analyze systems and products, implement, control, and supervise engineering solutions, communicate effectively, work as part of a team, lead, and maintain an ethical posture (BRASIL, 2019).

One of the ways to cultivate these skills in engineering graduates is through laboratory practices, as these spaces facilitate experiential learning.

In the field of grain automation and post-harvest management, there are excellent opportunities for the development of interdisciplinary practical content. Currently, due to the high grain production in response to global food demand, there is a need for secure and efficient storage processes. In this context, automation implementation emerges as an alternative to enhance these processes.

According to Feisel and Rosa (2005), Engineering is a field of knowledge in which practice is fundamental, as it combines the application of science to everyday life with the integration of theoretical and practical knowledge. Typically, theoretical concepts are taught in the classroom, while practical concepts are acquired in laboratories. Since the emergence of engineering schools in the 19th century, there has been a pursuit of balance between theory and practice.

Over the years, engineering curricula have become more theoretical, even though the industry still demands professionals with practical skills. Consequently, educational institutions began offering technology courses (also known as technologists) with shorter duration. Many professionals graduating from these technology programs ended up occupying positions that would traditionally be held by engineers, creating a certain conflict, as there is no clear distinction between the roles of these professionals educated in technology and engineering fields (Feisel and Rosa, 2005).

The performance of laboratory practices is essential in engineering courses as it allows for the exploration of diverse subjects from various perspectives, thereby aiding students in grasping abstract concepts. Chowdhurry et al. (2019) discuss the importance of employing educational laboratories in the context of engineering education, alongside the modeling and simulation of industrial processes. Consequently, there is a consensus on the relevance of educational laboratories. However, several factors limit their utilization, such as the high costs of facilities and the challenges of physically accommodating a large number of students, among other obstacles (Chowdhury et al., 2019).

In light of these considerations, the present study aims to survey and analyze the requirements for the development of an interdisciplinary educational laboratory in grain automation and post-harvest management for engineering education. The Quality House Matrix, an element of Quality Function Deployment, is used as an analytical tool, serving as an important support tool in determining design requirements in the informational design phase, as presented by Back et al. (2008).

2. MATERIALS AND METHODS

According to Maldaner et al. (2021), the Quality Function Deployment (QFD) method was created in the 1960s by professors Akao and Mizuno, with the aim of fulfilling customer desires and expectations during the development of a project. As per Back et al. (2008), the House of Quality is the initial matrix of the QFD used in this work.

It is recommended that the development of the House of Quality begins with gathering user requirements. In product development, user requirements are often scattered in unstructured information, so, as Back et al. (2008) suggest, such information should be sorted to identify qualities or desires that the product should incorporate. This information should be categorized based on their importance, thus completing the filling of the first field in the House of Quality.

In the second phase of the application, the engineering characteristics of the product are listed, which typically consist of parameters, physical quantities, functions, and product-specific constraints, as noted by Back et al. (2008).

In the center of the matrix, an analysis is performed regarding the impact of each engineering characteristic on user requirements, using a scale of strong, moderate, weak, or non-existent relationship intensity. As Back et al. (2008) suggest, the relationship intensity can be expressed by assigning values of 5, 3, 1, and 0, respectively. By multiplying the relative weight of each required quality by this relationship intensity and summing it in the column for each quality characteristic, the absolute weight of each characteristic is determined.

As a result, engineering characteristics are listed with different absolute and relative weights, which determine an order of importance in the design requirements.

According to Shahin and Ebrahimi (2020), the House of Quality systematizes a process that connects user requirements (what) with engineering characteristics, also known as technical specifications (how), as well as fields such as the weight of importance and an analysis of existing solutions in the market to address why. It is also notable that there is a field that mentions units of measurement, that is, how much, as shown in Figure 1.

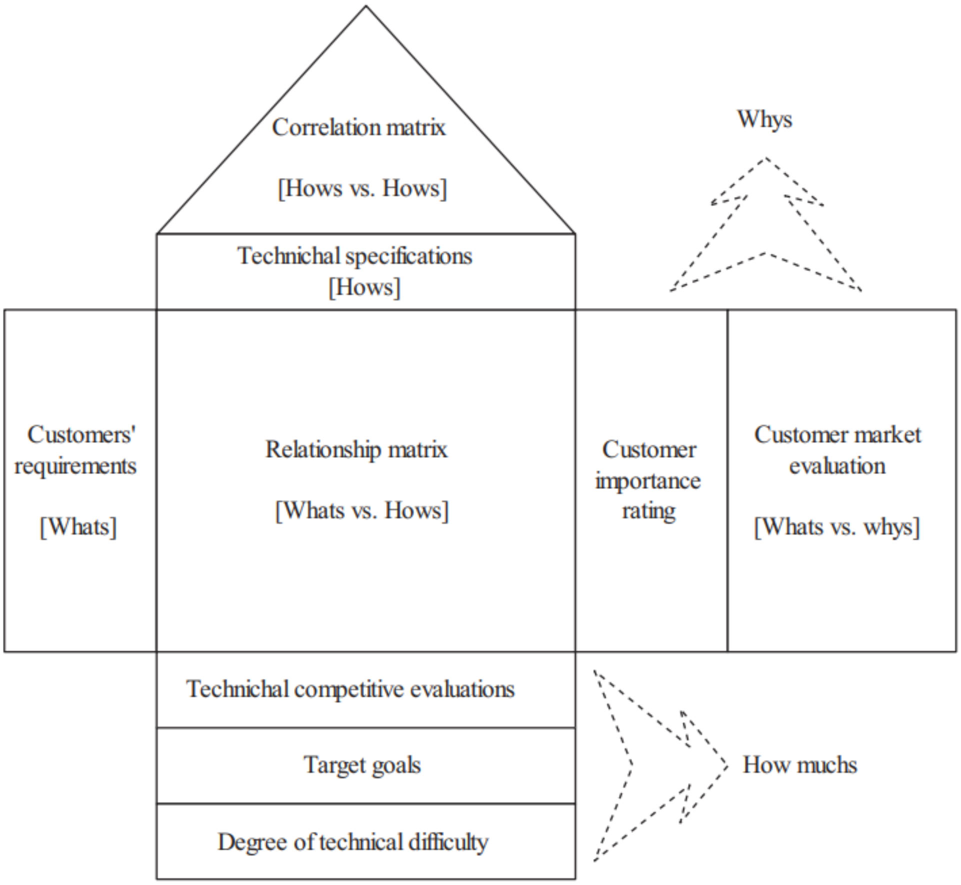


Figure 1. House of quality process (Shahin and Ebrahimi, 2020)

In Figure 2, Yan et al. (2022) illustrate the integration of the House of Quality between the informational design and other phases of the project, such as the preliminary and detailed design. It is evident that the prioritization of project requirements is reflected in specific characteristics of the final product that are critical to its success and acceptance.

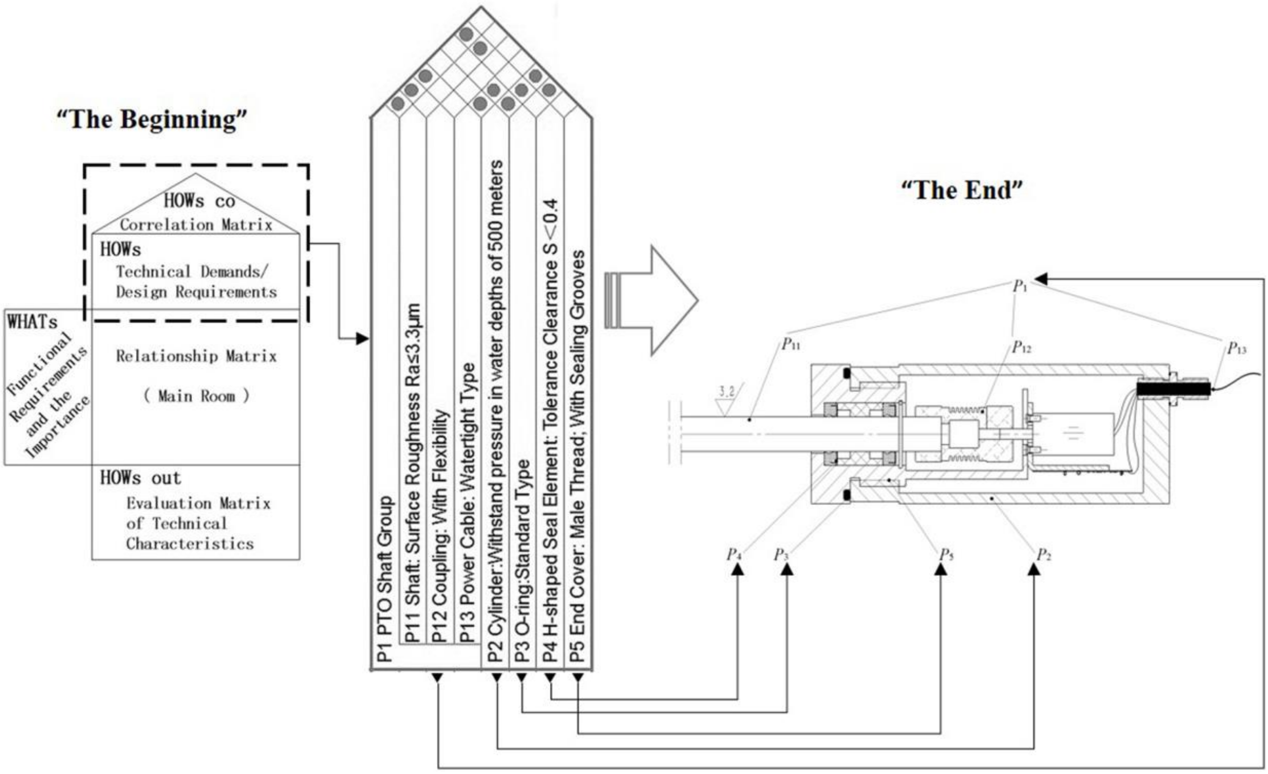


Figure 2. Relationship between design requirements and final product characteristics (Yan et al., 2022)

To list the user requirements, the work presented by Feisel and Rosa (2002), as cited in Krivickas and Krivickas (2007), identifies thirteen objectives related to pedagogical laboratory activities in engineering education. These objectives encompass: applying sensors and developing instrumentation to measure physical quantities in equipment and systems. Evaluating the accuracy of theoretical models in predicting the behavior of real systems. Specifying appropriate components and experimental approaches to characterize the behavior of engineering equipment and systems. Demonstrating creative thinking, autonomy, and problem-solving skills at suitable levels. Developing competence in using engineering tools, equipment, and resources. Identifying and addressing health, safety, and environmental aspects related to technological processes and activities. Communicating effectively about laboratory work with a specific audience. Working in teams, including task organization, management, responsibilities, and meeting deadlines. Demonstrating ethical and integral behavior in all activities. Possessing sensory awareness, using intuition and human emotions to gather information and draw conclusions about real-world problems.

A critical point in defining user requirements for a didactic laboratory is the analysis of the teaching methodological process, particularly emphasizing active methodologies. According to Bacich and Moran (2018), active methodologies emphasize the role of the student as the protagonist in the learning process, fostering interactions among peers, teachers, the academic community, and even society at large. Students actively engage in the process, involving themselves in the creation, experimentation, and reflection on the subject of study.

These methodologies are integrated into the context of improving traditional education, and for this purpose, it is essential for students to analyze their teaching process, identify gaps, and be self-critical, developing a reflective approach that enhances academic maturity and academic success (FERREIRA et al., 2018). In active learning, students go beyond merely listening, actively engaging in more complex thinking tasks with activities that stimulate them to do and reflect on what they are doing (BONWELL and EISON, 1991).

These active approaches align with theories such as the dialectical methodology in the classroom, as presented by Vasconcellos (1992), which aims to overcome issues of low interaction between the subject and the object of knowledge.

According to Vasconcellos (2000), the pedagogical task demands that those involved dedicate themselves to the object of knowledge proposed by the teacher. To transform this object into knowledge for the student, it is necessary to create a favorable learning situation, sparking the student's interest, questions, curiosity, and attention.

In this regard, Vasconcellos (1992) highlights the importance of the material expression of knowledge, enabling social interaction and a conclusive, specific, and tangible synthesis of the object of knowledge. When knowledge is only expressed mentally, there is a risk of generality and abstraction.

Bacich and Moran (2018) present various techniques for active learning, which are valuable when applied in a balanced manner to the institutional context. Among the primary techniques are Inquiry-Based and Problem-Based Learning, and Project-Based Learning.

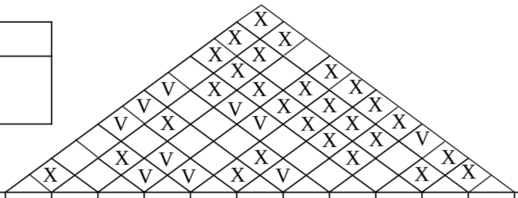
Based on the literature review related to engineering education presented in the work by Baal et al. (2023), user requirements and applicable engineering characteristics for the didactic laboratory, as well as the assigned weights of importance resulting from this analysis, are obtained.

3. RESULTS

Based on the aspects of active teaching methodologies and the goals of a hands-on approach to engineering education content, user requirements and engineering characteristics for the didactic laboratory are listed. An analysis of the relationship between these two domains is carried out in the body of the quality house, assigning values according to the relationship index, five for a strong relationship, three for a moderate relationship, one for a weak relationship, and no value when there is no connection between user requirements and engineering characteristics. On the roof of the quality house, the relationship between engineering characteristics is presented, which can be either positive or negative depending on the specificity of the characteristic. Figure 3 illustrates the completed quality house.

CORRELATION BETWEEN EF

V - Positive
X – Negative



Degree of relationship between User Requirements and Project Requirements

STRONG = 5
MODERATE = 3
WEAK = 1

User Requirements		Area (+) 1	Lighting (+) 2	Soundproofing (+) 3	Right foot height (+) 4	Quantity of equipment (+) 5	Number of tables and chairs for group work (+) 6	Nominal occupancy capacity (+) 7	Modularity (+) 8	Installation cost (-) 9	Maintenance cost (-) 10	Cost of operation (-) 11	DEGREE OF IMPORTANCE	RELATIVE WEIGHT (%)
		Engineering Features (EF)												
Have accessibility	1	5	3	1	1	3	3	0	1	3	1	1	5	11,4
Allow interaction between devices	2	5	1	1	3	5	3	5	3	1	1	1	3	6,8
Allow interaction between participants	3	5	3	3	0	3	3	5	0	1	1	1	5	11,4
Allow interaction between people and equipment	4	5	3	1	1	5	3	5	3	3	3	3	3	6,8
Have multidisciplinary flexibility	5	3	1	0	3	3	3	5	3	1	1	1	3	6,8
Be low cost	6	5	1	3	5	5	3	1	1	5	5	5	5	11,4
Allow inclusion or section equipment	7	0	0	0	3	5	3	5	5	3	3	3	2	4,5
Be safe	8	3	5	3	3	3	1	5	3	3	3	3	5	11,4
Provide concentration and focus for cognitive activities	9	5	5	5	3	1	3	5	1	3	3	3	4	9,1
Have adequate equipment to simulate processes	10	5	0	0	5	5	3	3	3	5	3	3	3	6,8
Have adequate space	11	5	3	3	5	1	3	5	1	5	5	5	4	9,1
Be suitable for different levels of education	12	1	1	1	1	3	3	3	0	5	5	5	2	4,5
WEIGHT OF IMPORTANCE		422,7	247,7	204,5	275,0	336,4	277,3	375,0	179,5	313,6	277,3	277,3	44	100
RELATIVE IMPORTANCE (%)		13,27	7,77	6,42	8,63	10,56	8,70	11,77	5,63	9,84	8,70	8,70		

Figure 3. House of quality for the didactic laboratory design

The analysis of the possibilities for the application of active teaching methodologies and the objectives for laboratory work elucidates user requirements related to interaction, involving individuals who would occupy the laboratory, including students, technicians, and instructors, in conjunction with the physical resources of the facility. Factors such as cost and safety also represent user requirements that have been highlighted. As for engineering characteristics, they pertain to the laboratory's infrastructure and costs. After assigning relationship points between user requirements and engineering characteristics, the order of importance of the engineering characteristics is determined to establish them as project requirements. The order of importance for the requirements is as follows: area, nominal occupancy, equipment quantity, installation cost, number of tables and chairs, installation cost, maintenance cost, operating cost, ceiling height, lighting, and sound insulation.

In the post-harvest stage of Agribusiness, the Grain Processing and Storage Units are an excellent opportunity for the development of practical interdisciplinary content in the area of automation. Aiming to achieve commercial standards, the cereal follows a way in the post-harvest unit that includes different equipment as shown in Figure 4. First, the grains are unloaded into the hopper (M) and transported by the elevator (E1) to the pre-cleaning machine (PL), which mechanically separates impurities from the grains. Then, through the elevator (E2) the grain is transported to the dryer (S), responsible for removing the water contained in the grains to the desired standard. Finally, the grains are transported through the elevator (E3) to the silo (SL) for storage until commercialization and dispatch to the industry. The Figure 4 presents a basic flowchart that may change depending on the particularities of each crop, for example, in many cases it is common for there to be another cleaning process between drying and storage.

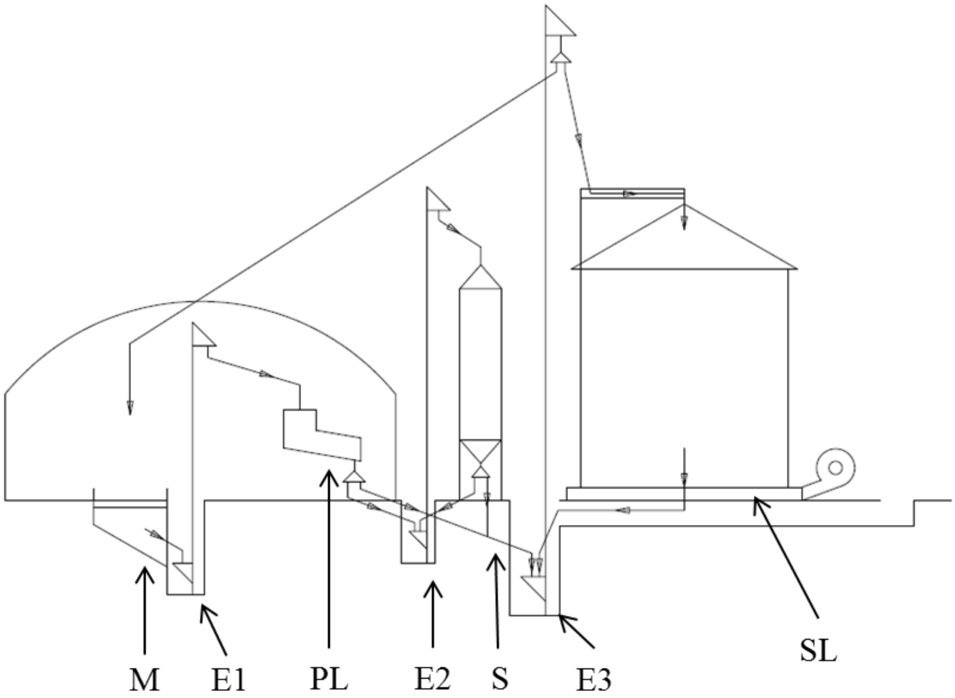


Figure 4. Processes in a Grain Processing and Storage Unit (Baal et al., 2023).

In addition to the basic flow described above, there is also auxiliary equipment used in the process, such as horizontal grain conveyors. Likewise, the grain dryer consists of a heat source, such as a furnace with a heat exchanger, this component can also be considered a separate piece of equipment.

There are several challenges in post-harvest processes, such as the need to keep the grains stored for considerable periods of time without loss of quality. On the other hand, installation configurations generate several risk factors capable of causing work accidents, such as confined spaces, work at heights, the presence of dust and explosive gases, as well as ergonomic aspects, such as repetitive operations, arduous work, among others (Baal et al. al. 2023). Automation has been applied in the post-harvest area, due to technological advances and cost reduction in the electronic area. Aiming to control the quality of the stored grain mass, digital sensors combined with concepts such as the Internet of Things are currently used in the grain aeration process.

Likewise, there are currently solutions on the market for monitoring and automating the post-harvest process as a whole. According to Kepler (2023), it is possible to monitor the operation of engines, fan speed, drying temperature, fuel supply to dryers, thermometry control for stored grains, control of loading and unloading of silos, through a centralized system supervisory system, which can be accessed remotely. It is noted that process automation presents itself as a viable solution for promoting full quality, covering both product quality and the promotion of health and safety at work and the environment.

4. FINAL CONSIDERATIONS

This work has introduced the House of Quality as part of the informational project for the development of an interdisciplinary laboratory in automation and post-harvest grain handling for engineering education. In this project phase, it is of paramount importance to define the requirements to be followed in the subsequent development stages. Therefore, the House of Quality serves as a valuable tool for the systematization of these requirements.

By prioritizing project requirements, there is increased assurance that the following project phases will be successful. As a continuation of this work, the aim is to further enhance the House of Quality with benchmarking, target values for engineering characteristics, and the other stages of the design process.

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