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RESEARCH PAPER

User-Centered Design and Usability Testing of an Air Handling Unit testing application: A Case Study

Pilar García, Maribel Amaya, Viridiana Silva-Rodríguez

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Abstract
In recent years, the design of user interfaces and user experience has become more relevant in companies due to the need to optimize the interaction between users and complex interactive systems. This study aims to establish design guidelines to improve the user experience in engineering applications in teams of Air handling unit testing engineers. A redesign process of a handling unit testing application was conducted using a user-centered design approach through in-depth interviews, user profiling, interactive prototyping, and usability testing. The results obtained showed a significant improvement in usability and user experience by implementing the fundamentals and principles of user-centered design. This case study highlighted the fundamental role of user interface and user experience design so that user interface designers and engineers can reference the learnings and findings to improve their applications to optimize the tasks of handling unit testing engineers.

Keywords:
User-Centered Design, Double Diamond, Usability Testing, Requirement analysis, Quality Enhancement.

1 Introduction
During a software development process, it is a priority to consider that software systems are easy to use, which is why software development teams have integrated user experience (UX) designers. However, the implementation of user-centered design (UCD) methods and fundamentals represents a challenge in a software development process [26]. User interface design improves the quality of a product through intensive communication with stakeholders.

In a context as specific as that of the Heating, Ventilation, and Air Conditioning (HVAC) industry, the efficiency and accuracy of testing ventilation units are crucial to ensuring the quality of the final product delivered to customers. Therefore, test engineers play a significant role in identifying faults in the unit control process. To perform these tests the test engineers, rely on applications that have been developed in-house based on some commercial applications and with additional required functionalities.

These applications for test engineers are generated in efficient and effective development environments for the management of digital control methods and tools of the cooling units, which allow the development of applications with graphical interfaces for ease of use.

In this context, software applications used by engineers to conduct these tests play a pivotal role. However, these applications traditionally focused primarily on operational correctness, neglecting critical aspects of the user interface (UI) and user experience (UX). This oversight led to significant usability issues, such as visual inconsistencies, poor information organization, and cumbersome navigation, all of which negatively impacted the efficiency and accuracy of the testing process [2, 4].

The main problem identified was that engineers had to work with interfaces that were not user-friendly, which increased the learning curve and reduced overall productivity. The application's design flaws hindered the engineer's ability to perform tasks efficiently and accurately, leading to potential errors and decreased job satisfaction.

To tackle these challenges, a user-centric redesign was proposed, adhering to the company's design guidelines. The goal was to optimize usability and ensure long-term sustainability. Central to this case study was an analysis using the Double Diamond methodology, which consists of four key stages: Discover, Define, Develop, and Deliver. This method provides a user-centered approach to developing creative solutions, allowing exploration and refinement of different ideas to arrive at an effective solution while reducing the risk of moving forward with an inadequate solution [9].

This structured approach systematically addressed the initial shortcomings of the application, resulting in a product that better serves the needs of engineers and contributes to more efficient and accurate testing of ventilation units. This case study highlights the importance of incorporating comprehensive user design analysis into system development, rather than focusing solely on functional aspects. By addressing both usability and operational correctness, we can create more effective and user-friendly applications that enhance overall performance and user satisfaction.

2 Related Work
Several studies have explored the importance of UCD in enhancing usability, particularly in technical and engineering contexts. A study in 2021 highlights the critical role of UCD in the development of energy management systems, emphasizing the need for intuitive interfaces to improve user interaction and system efficiency. The researchers found that by focusing on the users' needs and

García P., Silva V.
Daikin Applied Americas
San Luis Potosí, México
Email: {pilar.garcia, viridiana.silva}@daikinmx.com

Amaya M.
Instituto Tecnológico de San Luís Potosí
San Luis Potosí, México.
Email: L19180887@slp.tecnm.mx

preferences, the system's usability and overall performance were significantly enhanced [21].

Similarly, the application of user-centered design (UCD) principles in developing smart grid applications focuses on prioritizing the needs and experiences of the end users throughout the design process. Their findings indicate that user-friendly designs not only enhance operational efficiency but also improve user satisfaction in managing complex engineering systems. The study demonstrates how involving end-users throughout the design process can lead to more effective and user-friendly solutions [13].

In the context of Human-Centered Virtual Assistants (HVA), the integration of user-centered design (UCD) is crucial for creating more effective and user-friendly interactions. HVAs designed with a user-centered approach can better understand and respond to the needs of users, leading to improved usability and acceptance of the technology.

These studies underscore the relevance of user-centered design (UCD) in our project, where the primary goal is to improve the usability of an application designed for test engineers. By integrating UCD principles, we aim to address the specific needs and preferences of the end users, ensuring that the application is not only functional but also intuitive and easy to use [13, 19, 21].

3 Research Methodology

The main objective of this study was to enhance the usability of an air conditioning device testing application through a user-centered design approach. Specifically, the study aimed to:

3.1 User Centered Design

A user-centered design approach begins with a thorough understanding of user needs, pain points, and workflows. By conducting in-depth interviews with end-users, the design team gains valuable insights into the challenges engineers face when using the application. By involving users throughout the design process, from initial concept to final implementation, the application can be optimized for usability and user experience. This includes designing a more intuitive interface, organizing information more effectively, and simplifying task flows.

By incorporating user feedback and iterative design improvements, the application remains relevant and effective over the long term. User-centered design ensures that the application evolves with user needs and technological advancements, ensuring its sustainability.

To address these challenges and leverage the benefits of a user-centered design approach, this case study employed the Double Diamond methodology [5, 6, 7, 15, 17, 20].

3.2 Double Diamond Methodology

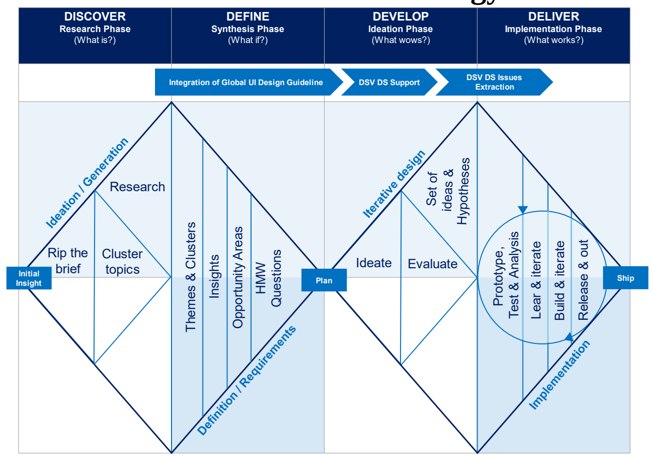

Figure 1. Double Diamond Diagram (It is a guide about the process we followed for the project).

Central to this redesign was the adoption of the Double Diamond methodology, a well-established framework that guides teams through the design process. The Double Diamond methodology consists of four key stages: Discover, Define, Develop, and Deliver, each of which plays a crucial role in understanding user needs, defining problem areas, developing solutions, and delivering a refined product. The methodology consists of the following stages:

- Discover: This initial stage focuses on exploring and identifying user needs and problems. It involves gathering insights and understanding the context of the users and their interactions with the application.
- Define: In this stage, the gathered information is analyzed to pinpoint the core issues. Creating detailed user profiles and personas ensures that design decisions are tailored to meet the specific requirements of diverse user groups.
- Develop: This phase involves brainstorming and developing high-fidelity prototypes using tools like Figma. The prototypes are iteratively refined based on continuous user feedback, focusing on visual consistency, information hierarchy, and navigation improvements.
- Deliver: The final stage involves the implementation and launch of the product. Continuous evaluation and feedback are crucial for ensuring the product's quality and effectiveness, followed by iterative improvements based on user input.

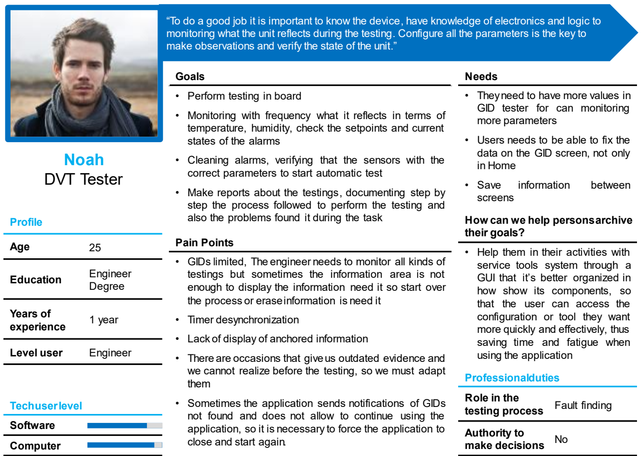

Figure 2. User Profile (Information obtained and analyzed of the interviews).

The iterative nature of the Double Diamond methodology is essential as it allows for continuous improvement and adaptation throughout the design process. This iterative approach ensures that the final product is not only functional but also intuitive and user-friendly, contributing to more efficient and accurate testing of ventilation units. By incorporating user feedback at each stage, this approach helps in creating a product that meets the needs of engineers, enhances usability, and supports the overall goals of the organization [9, 19].

3.3 Optimize usability

The efficiency and accuracy of testing ventilation units are critical in delivering high-quality products to customers in the Heating, Ventilation, and Air Conditioning (HVAC) industry. Central to this process are the software applications used by engineers for conducting these tests. Traditionally, the focus of such applications has been primarily on operational correctness, often neglecting the critical aspects of user interface (UI) and user experience (UX). This oversight can lead to significant issues, including visual inconsistencies that affect brand image, as well as problems with information organization and task execution within the application. A cluttered user interface (UI), redundant information, and specific task pathways can make the application cumbersome and difficult to use.

By improving the user interface and experience, the application becomes more intuitive and user-friendly. This not only reduces the learning curve for inexperienced users but also enhances the efficiency and accuracy of tasks performed by engineers. Through user-centric redesign and application of interaction design principles, usability issues such as visual inconsistencies, information organization problems, and complex task pathways can be systematically addressed.

Optimizing usability ensures that the application remains effective and relevant over the long term. By incorporating user feedback and iterative design improvements, the application can evolve to meet changing user needs and technological advancements [4, 10, 25].

4 Enhancing and Validation Usability

Usability testing, such as the System Usability Scale (SUS) and the Post-Study System Usability Questionnaire (PSSUQ), provides quantitative measures of the application's usability improvements. It confirms whether the redesign efforts have successfully addressed the identified usability issues, such as interface intuitiveness, information organization, and navigation improvements. Validating through usability testing ensures that the application remains relevant and effective over time. By incorporating user feedback and making iterative improvements, the application evolves to meet changing user needs and technological advancements, ensuring its long-term sustainability.

All application end users were contacted via email to participate in interviews. A company-provided user list was used to ensure a representative sample. The interviews were conducted remotely, providing participants with flexibility and comfort. Each session was recorded and transcribed to facilitate accurate analysis and extract valuable insights.

After gathering and analyzing the interview data, the next step was to create user personas—fictitious yet realistic representations of end users. These personas allowed us to empathize with users and better understand their needs and expectations. This insight helped shape the design of the application to meet the specific requirements of different user groups, ensuring that the interface and functionality were accessible and intuitive for all. For example, personas enabled us to prioritize features and design elements based on their relevance to users, from beginners to advanced technicians. By focusing on these personas, we crafted a more personalized and effective user experience that addressed the unique challenges of our diverse user base.

In conclusion, usability testing validated the success of our user-centric redesign, ensuring that the application not only met but exceeded user expectations. This step was integral to the Double Diamond methodology, guiding the iterative design process and contributing to the overall success of the project.

5 Prototyping

Prototypes play a crucial role in software development, acting as preliminary and incomplete representations of a product to evaluate and improve it before extensive resources are invested. The main purpose of a prototype is to identify potential improvements, corrections, or additions to the application. Prototyping proved especially beneficial in the initial stages of the design process, facilitating exploration and ideation. By rapidly creating and testing distinctive design and organizational concepts, we identified promising solutions and highlighted those that did not work, thereby avoiding unnecessary investment in unfeasible ideas [2, 8, 11, 24] .

Low and high-fidelity prototypes were created. The low-fidelity prototype served as a simplified and basic version of the application design, focusing on points such as size, organization, or The System Usability Scale (SUS). For a more detailed analysis of these results, see the Results and Discussion section.

6 Rigorous Usability Testing

Usability testing is a critical component in the redesign process, ensuring that the final product meets user needs and expectations. Our approach involved rigorous testing using established metrics such as the System Usability Scale (SUS) and the Post-Study System Usability Questionnaire (PSSUQ) [14]. These evaluations were conducted on 28% of the end users and yielded reliable results.

6.1 System Usability Scale (SUS)

The System Usability Scale (SUS), developed by John Brooks in 1986, evaluates how effectively users can complete tasks and their satisfaction with the system. SUS includes ten questions rated on a 5-point Likert scale, providing insights into the user experience.

Our SUS results were positive, indicating high user satisfaction with ease of use and system confidence. For a more detailed analysis of these results, see the Results and Discussion section [3, 22, 20].

6.2 Post-Study System Usability Questionnaire (PSSUQ))

The Post-Study System Usability Questionnaire (PSSUQ), developed by IBM in the 1990s, measures user satisfaction across three areas: Usefulness, Information Quality, and Interface Quality. With sixteen questions rated on a 7-point Likert scale, PSSUQ provides a nuanced view of user experience. Applying PSSUQ helped us identify specific areas for improvement. Detailed findings are presented in the Results and Discussion section [17, 23].

6.3 Usability Testing Activities

We conducted a series of activities on each device to assess the usability and functionality of the system. These activities included:

- Logging in: Evaluates the clarity and efficiency of the login process.
- Connecting to unit ventilator: Assesses the system's connectivity to external devices.
- Changing and saving parameters: Tests the user interface for managing system parameters.
- Performing search tasks on the new help screens: Evaluates usability of the help and support features.

We employed the "think aloud" technique to capture user thoughts and reactions during these tasks. This method provided detailed feedback on system interactions and highlighted areas for improvement.

The results from the SUS and PSSUQ tests highlight the effectiveness of the user-centered design approach. Users found the system intuitive, which is reflected in their high satisfaction scores.

The detailed results show that user-centered design significantly enhances usability and productivity. Future research should build on these insights, exploring broader user demographics and additional aspects like performance and security. This study provides a model for integrating user feedback into design processes, which can guide future projects in creating more effective and user-friendly applications [1, 14].

7 Evaluation and Optimization

During the usability testing phase, we identified several key metrics and findings that guided our optimization efforts:

- Task Completion Rates: High rates indicated the system effectively supported users in achieving their goals.
- Time on Task: Reduced time compared to previous versions suggested improved efficiency.
- Error Rates: Fewer errors highlighted enhanced usability and error recovery.
- SUS Scores: An average SUS score above 80 demonstrated strong user satisfaction.
- PSSUQ Scores: Positive feedback on usefulness, information quality, and interface quality reflected high user satisfaction.

To optimize testing, we analyzed use cases provided by test engineers, noting varying levels of activity complexity. We focused on repetitive and relevant activities to create test cases that mirrored real user interactions. This approach balanced guidance and user autonomy, reducing the risk of bias and ensuring a realistic testing environment. By generalizing activities and minimizing explicit instructions, we aimed to better reflect actual user experiences and needs.

8 Challenges or Limitations

In the realm of industrial engineering, particularly within the scope of Air Handling Unit (AHU) testing, usability often takes a backseat to functionality and performance. However, the efficiency and accuracy of test engineers can be significantly enhanced through thoughtful user-centered design. This case study focuses on a usability improvement initiative for an Air Handling Unit (AHU) testing application in San Luis Potosí, México. By applying user-centered design principles, the goal was to create a more intuitive and efficient interface that meets the specific needs of test engineers.

The redesign process posed unique challenges beyond simply creating visually appealing, intuitive, and user-friendly interfaces. Ensuring adaptability across different devices and maintaining a cohesive experience were important, but the most significant challenge was achieving acceptance of design best practices among the engineers. In applications that traditionally focus solely on functional aspects to solve logical issues, design considerations are often neglected. Engineers, accustomed to a certain way of working, can be resistant to change, making it difficult to implement improvements even if they benefit the user.

This resistance stems from a focus on functionality, with little consideration for the overall user experience. Convincing engineers of the value of design changes required extensive testing and demonstration of the benefits. By displaying more attractive and efficient methods, while ensuring that changes met with their approval, we were able to gradually introduce improvements. This study documents the journey from identifying usability issues to implementing effective solutions. Through a series of user interviews, observational studies, and iterative design cycles, we developed an application that significantly improved the user experience. The findings from this case study underscore the value of incorporating user feedback into the design process and highlight the tangible benefits of a user-centered approach in industrial applications.

9 Results and Discussion

Usability tests revealed that users found the system intuitive and easy to use, significantly enhancing their productivity. They were able to complete tasks quickly, and the clarity of the information displayed on the interface was noted as a key factor. This clarity reduces the likelihood of errors and supports better decision-making both within and outside the application. Users expressed high satisfaction with the new interface, feeling that it met their expectations and provided all necessary features.

These findings reaffirm the crucial role of user-centered design in creating effective and successful products. The UCD process employed in this project has proven to be a vital element in achieving a design that is both functional and appealing. By focusing on usability, we have highlighted how critical it is to place the user at the center of the design process. This approach not only enhances the attractiveness of the application but also ensures its functionality and accessibility, which reduces the learning curve and boosts productivity.

The results of this study underline the importance of user-centered design in software development. The positive impact observed in usability suggests that involving users in the design process and addressing their needs and preferences can lead to more effective and user-friendly applications. This approach contrasts with other areas of application design where user feedback may not be as central, showing that a focus on usability can lead to significant improvements in overall user satisfaction and efficiency.

However, there are some limitations to consider. The study was conducted with a specific user group, and while the results are promising, they may not be fully generalizable to all potential users. Future research should involve a broader and more diverse user base to validate these findings further. Additionally, while this study focused on usability, it is important to also consider other factors such as application performance and security in future iterations. This research contributes to the field by providing a model for integrating user-centered design into the development of AHU applications. The approach demonstrated in this study can serve as a guide for future projects aiming to enhance usability and user satisfaction. Future work should continue to explore and refine these practices, considering the evolving needs of users and advancements in technology.

In conclusion, the positive outcomes of this study emphasize that user-centered design is a fundamental component of successful software development. By ensuring that the user remains at the core of the design process, developers can create applications that are not only aesthetically pleasing but also highly functional and user-friendly.

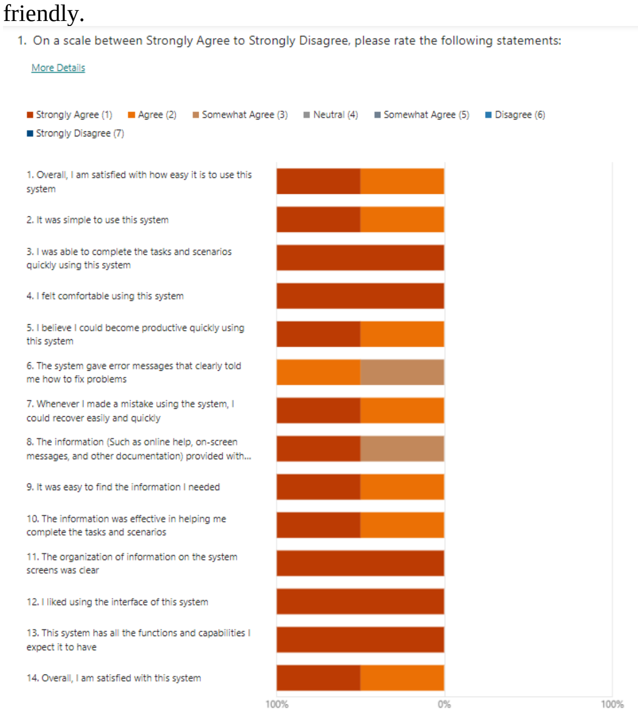

Figure 3. Results of the completed application (PSSUQ).

10 Conclusions

Through a structured process involving interviews, user personification, prototype development, and usability testing (using SUS and PSSUQ), we obtained a comprehensive understanding of user interactions with the system. Initial interviews and observations of user behavior allowed us to identify genuine user needs, expectations, and challenges. This information was crucial for creating accurate user personas, which guided the design of prototypes to ensure that the system addressed specific and relevant issues for the users.

Adopting a user-centered design approach enabled us to place users at the core of the development process. This approach not only improved usability but also significantly increased user satisfaction by providing solutions that met their needs and expectations. The iterative process of prototyping and continuous refinement, based on valuable direct user feedback, allowed us to optimize the design to be both intuitive and highly effective.

The user-centered approach facilitated the identification of both the strengths of the application and the areas needing improvement. By prioritizing a user-centric methodology, we ensured that each update progressively aligned the application with the evolving needs and expectations of our users. This approach led to a more natural and satisfying solution for the end user.

A key differentiator in our process was the emphasis on continuous testing and feedback during the development phase. This commitment to ongoing testing allowed us to address user concerns in real-time and refine the application iteratively. Engaging engineers in this continuous testing process was critical to overcoming resistance to change, as it demonstrated the tangible benefits of the improvements and fostered a collaborative environment. This practice not only improved the final product but also helped in gaining the engineers' trust and buy-in for future enhancements.

In summary, the implementation of a user-centered design methodology proved to be highly effective in enhancing the usability and user satisfaction of the Air Handling Unit (AHU) testing application. The iterative design and testing processes were instrumental in creating an interface that not only met functional requirements but also provided a seamless and intuitive user experience. This case study demonstrates the significant benefits of incorporating user feedback into the development cycle and highlights the importance of addressing user resistance to change through demonstrable improvements and engagement. The ongoing testing process made a crucial difference, driving the project's success and ensuring continued commitment to user-centric development.

11 Acknowledgments

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