JPPIPA 11(4) (2025)

Jurnal Penelitian Pendidikan IPA

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Air Management in Chemistry Laboratories to Prevent Sick Building Syndrome (SBS): A Mixed-Method Approach

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Received: January 08, 2025
Revised: March 05, 2025
Accepted: April 25, 2025
Published: April 30, 2025

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DOI: 10.29303/jppipa.v11i4.10799

Abstract: Chemistry laboratories are inherently high-risk environments where poor Indoor Environmental Quality (IEQ) can contribute to Sick Building Syndrome (SBS)—a condition marked by symptoms such as headaches, respiratory irritation, and reduced concentration, which negatively affect user productivity and well-being. Ensuring optimal air circulation is critical to maintaining thermal comfort, air quality, and compliance with occupational health and safety standards. This study adopts a mixed-method approach using a sequential exploratory design to investigate user comfort perceptions in chemistry laboratories. Data were collected through surveys of 50 respondents from five educational institutions to capture the Voice of Customer (VoC) regarding environmental comfort. Qualitative findings were enriched through benchmarking and further analyzed using the House of Quality (HoQ) method to identify air circulation deficiencies and prioritize improvements. The analysis revealed that educational laboratories underperform in temperature control, humidity regulation, and air freshness when compared to industrial and training laboratories. Key factors affecting comfort include air circulation pathways (score = 42) and air regulation mechanisms (score = 36), followed by circulation points (score = 21) and air conditioning systems (score = 11). The proposed solution involves integrating cassette-type air conditioners with a Louver Fresh Air (LFA) system to enhance thermal stability and ensure fresh air exchange. These improvements are vital for preventing SBS, enhancing user well-being, and supporting effective laboratory-based learning.

Keywords: Air Circulation; Chemical Laboratory; Sick Building Syndrome.

Introduction

The health and safety of chemistry laboratory users is a critical issue due to the various potential health risks associated with laboratory environments. Chemistry laboratories often involve the use of volatile chemicals, toxic substances, and equipment that generates heat, all of which contribute to the degradation of indoor air quality (IAQ) and increase the risk of Sick Building Syndrome (SBS). Exposure to poor IAQ can lead to respiratory problems, headaches, eye irritation, and reduced cognitive function, ultimately affecting the productivity and well-being of laboratory user (Deng et al., 2024; Niza et al., 2024). The indoor environmental conditions of chemistry laboratories must be carefully managed, as they have a direct impact on users' health (Brink et al., 2021; Sadrizadeh et al., 2022). Studies highlight that poor ventilation, high humidity levels, and chemical pollutants are major contributors to deteriorating IAQ, leading to long-term health concerns

How to Cite:
Abdurrasyid, Geisfarad, H., Pamungkas, R. A., Yanti, A. R., Elnastio, D., & Wahyudin, D. (2025). Air Management in Chemistry Laboratories to Prevent Sick Building Syndrome (SBS): A Mixed-Method Approach. *Jurnal Penelitian Pendidikan IPA*, *11*(4), 1047-1058. https://doi.org/10.29303/jppipa.v11i4.10799

(Reuben et al., 2019). Ensuring adequate air circulation and filtration systems is therefore essential in reducing exposure to harmful airborne substances and maintaining a safe and comfortable working environment (Elsaid & Ahmed, 2021; Kumar et al., 2023).

Recent research underscores the importance of proactive air quality management in laboratories. Implementing advanced ventilation strategies, such as high-efficiency particulate air (HEPA) filtration, real-time air quality monitoring, and controlled ventilation systems, can significantly mitigate health risks and enhance occupational safety (Azmi et al., 2022; Weschler & Carslaw, 2018). Additionally, the design and maintenance of air circulation pathways, including the strategic placement of exhaust systems and air exchange mechanisms, play a crucial role in minimizing the accumulation of hazardous compounds (Adepoju et al., 2024; Richardson & Theodore, 2024). Furthermore, understanding the dynamics of indoor air regulation is fundamental to improving air quality standards and ensuring a healthier laboratory environment. Research suggests that continuous assessment of laboratory air quality parameters, such as temperature, humidity, CO_2 levels, and volatile organic compounds (VOCs), is necessary to prevent adverse health effects and optimize laboratory safety protocols (Danza et al., 2020). However, most of the existing research focuses more on air quality measurement and risk factor identification without integrating user perspectives directly in the design of air circulation systems. In addition, the technical approaches used have not incorporated many systematic methods such as Voice of Customer (VoC) and House of Quality (HoQ) to translate user needs into technical specifications for an optimal circulation system. This suggests a research gap in the development of a system design that is both user-centered and data-driven.

Sick Building Syndrome (SBS) is a health-related condition closely linked to indoor air quality (IAQ) within enclosed spaces (Mansor et al., 2024; Marlina et al., 2023; Maulianti et al., 2021; Niza et al., 2024; Surawattanasakul et al., 2022). SBS manifests as a physiological response to indoor air pollution, leading to symptoms such as headaches, eye irritation, respiratory discomfort, and fatigue (Aziz et al., 2023).

SBS is primarily caused by poor indoor air quality, which is influenced by several factors, including microbial contamination, the presence of volatile organic compounds (VOCs), and inadequate ventilation systems (Reuben et al., 2019; Salthammer et al., 2010). These factors contribute to the accumulation of airborne pollutants that negatively impact occupants' health.

Chemistry laboratories, as educational facilities, frequently store volatile organic compounds such as benzene, formaldehyde, and other irritants, which can significantly increase the risk of SBS among laboratory users. Without adequate ventilation and air filtration systems, exposure to these airborne chemicals can lead to adverse health effects, compromising the well-being and cognitive function of laboratory occupants. To mitigate these risks, it is essential to implement effective air quality management strategies, including proper ventilation design, control of VOC emissions, and air purification systems. Ensuring a well-regulated airflow within laboratories can help reduce the incidence of SBS and create a safer and healthier indoor environment for users.

Several environmental factors, including condensation, humidity levels, and unstable temperatures, have been associated with the onset of Sick Building Syndrome (SBS). These factors highlight the crucial role of air circulation in preventing SBS by ensuring proper indoor air quality management (Nakayama et al., 2019). Preventive measures against SBS should prioritize indoor air quality control, particularly in chemistry laboratories, which pose a high risk of pollutant exposure (Zumrut et al., 2022). Implementing an effective air circulation system is essential to regulate air pollutant levels and improve indoor air quality, thereby reducing the risk of SBS (Spinazzè et al., 2022).

A comprehensive approach to SBS prevention in chemistry laboratories must take into account multiple factors, including contaminant levels, the presence of volatile organic compounds (VOCs), user behavior, and air circulation system design. Proper ventilation and airflow management in chemistry laboratories can effectively minimize SBS risks, ensuring that laboratory users remain healthy and productive (M. Wang et al., 2022). Furthermore, air circulation system design is directly linked to indoor air quality and SBS prevalence (Hou et al., 2021). The establishment of thermal comfort through a well-structured air circulation system plays a critical role in mitigating various health complaints associated with SBS. Optimizing temperature, humidity, and air distribution within laboratory spaces can significantly reduce SBS-related symptoms while enhancing overall occupational well-being and efficiency (Aziz et al., 2023; Hou et al., 2021).

Extensive literature reviews have emphasized the critical relationship between effective indoor air circulation and the prevention of Sick Building Syndrome (SBS), highlighting the necessity of well-designed ventilation systems to mitigate health risks associated with poor indoor air quality (M. Wang et al., 2022). In response to these findings, ongoing research and innovation remain essential in advancing technologies and methodologies for optimizing air circulation, ensuring that enclosed environments, particularly chemistry laboratories, maintain high air quality standards to prevent SBS (Reuben et al., 2019).

Addressing these challenges, this study aims to develop a systematic framework for designing an optimized air circulation system, integrating the Voice of Customer (VoC) approach to align with the specific needs of laboratory users. The design process is further structured through the House of Quality (HoC) method, enabling a quantitative assessment of air circulation quality requirements and ensuring that the system effectively minimizes SBS risks. By establishing a comprehensive understanding of air circulation dynamics, this study seeks to provide valuable contributions to educational institutions undertaking laboratory renovations or new constructions, facilitating the development of safe, healthy, and productive learning environments. The integration of user-centered design principles, coupled with rigorous quality assessment methodologies, is expected to serve as a benchmark for future innovations in air circulation systems, ultimately reducing SBS prevalence and enhancing occupational well-being and productivity in high-risk indoor environments.

This research offers a new approach by developing a systematic framework in the design of laboratory air circulation systems that combines the Voice of Customer (VoC) approach and the House of Quality (HoQ) method. The integration of these two approaches allows system design that is not only based on technical parameters alone, but also considers the perceptions, needs, and complaints directly from laboratory users. Thus, this research brings together the technical and human-centered dimensions in one comprehensive ventilation system design framework-something that has not been found in previous literature.

This research is important because of the increasing concern for the health and comfort of indoor space users, especially in the context of chemical laboratories that have a high risk of pollutant exposure. Without a well-designed air circulation system, the risk of SBS not only impacts the health of users, but also on work productivity and safety. In addition, the results of this study are expected to provide practical guidelines for educational institutions in designing or renovating laboratories that are healthier, safer, and more productive. The user needs-based approach used in this study also has the potential to be replicated in other indoor work environments that have similar risks.

Method

The research method employed in this study follows a mixed-method approach with a sequential exploratory design, integrating qualitative and quantitative methods through an instrument development model to design an air circulation system that meets user requirements for comfort while mitigating the risk of Sick Building Syndrome (SBS). The study utilizes Voice of Customer (VoC) data, which captures users' perceptions of comfort in chemistry laboratory spaces across five university-level educational laboratory facilities (Arts, 2022; Moore, 2023). VoC data is analyzed using a qualitative phenomenological descriptive approach to gain deeper insights into user experiences. The study involves 50 respondents, selected through Accidental Sampling from the five chemistry laboratories, with laboratories chosen based on accreditation criteria for higher education institutions. Subsequently, VoC data is processed using the House of Quality (HoQ) framework to establish air circulation system specifications, which are then used to design an optimized air circulation system tailored for chemistry laboratories in educational programs. The final design is developed and visualized through Computer-Aided Design (CAD) software, producing a comprehensive air circulation network diagram to facilitate effective implementation.

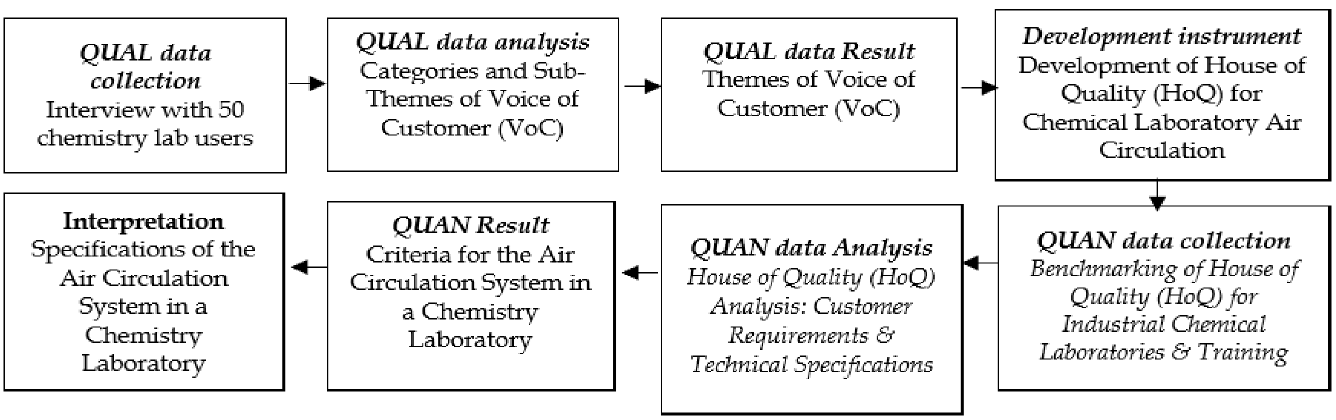

Figure 1. Research Procedures

Result and Discussion

The development of an air circulation system in chemistry laboratories is illustrated to accommodate a maximum area of 100 square meters, with a user capacity of 30 individuals per room. Ensuring user comfort in laboratory spaces is crucial, as chemistry laboratories serve as high-risk learning environments, requiring strict adherence to occupational health and safety standards. Given the critical role of laboratory infrastructure in supporting effective education, optimizing facilities and amenities is essential to enhancing educational quality. One of the key aspects of this improvement is the design of an efficient air circulation system tailored to chemistry laboratory environments, ensuring a safe, comfortable, and conducive space for learning and research activities.

Voice of Customer (VoC)

Voice of Customer (VoC) represents the perceptions of chemistry laboratory users regarding the comfort levels experienced after engaging in laboratory activities for at least 30 minutes. The VoC data was collected from 50 laboratory users across five different chemistry laboratories in various educational institutions (Figure 2).

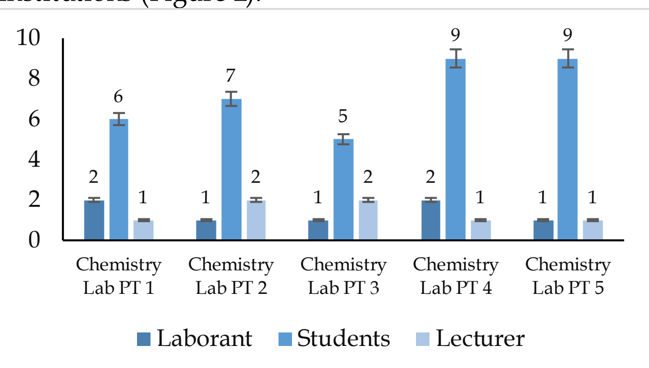

Figure 2. The distribution of respondents identified from the chemistry laboratory (n = 50 participants)

The respondents consist of various user groups, including 7 laboratory staff (14%), 36 students (72%), and 7 faculty members (14%). As shown in Table 1, the distribution of respondents—comprising laboratory staff, students, and faculty members—across five chemistry laboratories in higher education institutions demonstrates variations in user engagement.

The user distribution in chemistry laboratories reveals a clear dominance of students as the primary users across all observed institutions. Laboratories in PT 4 and PT 5 recorded the highest number of student users, with nine individuals each, followed by PT 2 with seven students, PT 1 with six, and PT 3 with five. This trend underscores the central role of students in laboratory-based learning activities. In contrast, laboratory staff constitute a smaller portion of the user population, with only one to two individuals per laboratory. Their presence suggests a managerial and supervisory role rather than active, hands-on utilization of the laboratory. Faculty members, meanwhile, represent the smallest user group, with only one or two individuals per laboratory, indicating their involvement is more aligned with providing oversight and academic guidance. While the number of students varies slightly among the institutions, their dominance is consistent, whereas the distribution of staff and faculty members remains relatively stable. This variation reflects differing intensities of laboratory usage but a shared structure in user roles across the institutions.

These findings highlight that student are the primary users of chemistry laboratories, while laboratory staff and faculty members primarily contribute to management and supervision. This insight serves as a crucial consideration in designing an optimal air circulation system, ensuring that the system aligns with the primary needs of students as the dominant user group.

The initial analysis phase was conducted using content analysis, where researchers identified key terms (text data) from respondents' perceptions regarding the sub-theme of comfort in the laboratory environment. Text data analysis aimed to identify common perceptions about the criteria for laboratory comfort by grouping similar keywords into broader sub-themes. The identification and categorization process resulted in several sub-themes, which were then used to generate a frequency distribution to determine the most dominant sub-themes (Figure 3).

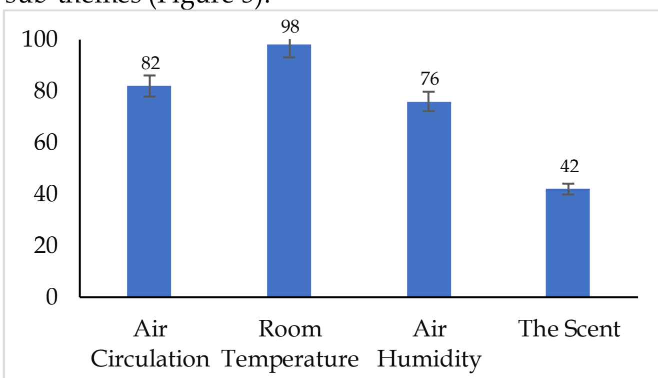

Figure 3. Analysis of the distribution of perception regarding comfort criteria in the chemistry laboratory (n = 50 participants)

The analysis of key factors influencing the comfort of chemical laboratory environments, as illustrated in Table 2, highlights critical aspects shaping users' perceptions of indoor air quality. Four primary factors—air circulation, room temperature, humidity, and odor—

demonstrate varying degrees of significance in determining laboratory users' comfort and well-being.

Room Temperature as the Most Influential Factor

The data indicate that room temperature (98 responses) is the most frequently mentioned factor affecting comfort, underscoring its crucial role in creating a conducive working environment. Temperature fluctuations can negatively impact concentration, productivity, and users' health, necessitating effective thermal regulation strategies in laboratory management.

The Importance of Air Circulation and Humidity Control

Air circulation (82 responses, 27.5%) and humidity levels (76 responses, 25.5%) were also identified as key contributors to comfort. Inadequate air circulation can lead to stagnant airflow, increased airborne contaminant concentrations, and exacerbation of Sick Building Syndrome (SBS) symptoms. Similarly, improper humidity regulation can affect user well-being and the stability of laboratory equipment. These findings emphasize the need for a well-integrated ventilation system to enhance indoor air quality and mitigate health risks.

Odor as a Secondary but Relevant Factor

Although odor received fewer responses (42 responses), it remains a relevant concern. Chemical laboratories often contain volatile organic compounds (VOCs) that can generate unpleasant odors, cause discomfort, and potentially irritate the respiratory system. Therefore, effective air filtration and odor management strategies should be implemented to maintain a high-quality indoor environment.

These findings reinforce the necessity of a comprehensive air circulation strategy tailored to the specific needs of laboratory users. Ensuring optimal temperature control, efficient ventilation, and appropriate humidity levels is crucial in creating a safe, comfortable, and productive working environment. This study provides a foundation for developing more advanced air circulation system models with user-centered design approaches, ultimately improving overall laboratory conditions and minimizing risks associated with suboptimal indoor air quality.

The sub-theme of room temperature emerged as the most frequently mentioned factor by respondents, with concerns such as "the room does not feel cool," "the room feels hot," "the room feels stuffy," "the room is not refreshing," "it is easy to feel overheated while engaging in activities inside the room," "frequent thirst when working in the laboratory," and "sweating quickly when performing activities in the laboratory." The next most frequently mentioned sub-theme was air circulation, with respondents often stating that "there is no noticeable airflow" and "there is no breeze."

The sub-theme of humidity was frequently expressed by respondents through statements such as "equipment and materials are prone to mold," "powdered substances tend to clump when stored in the room," and "some laboratory furniture has mold growth." Lastly, the sub-theme of room odor was highlighted by respondents through perceptions such as "there is an unpleasant smell in the lab," "a strong odor causes dizziness," and "the lab environment induces nausea." An excerpt from one of the respondents illustrates this concern:

"The chemistry laboratory room for practicums should be more comfortable than the current condition, because in the chemistry lab room it feels hot, stuffy, and not cool even though there is a room that is given air conditioning, not to mention when storing the material, sometimes if it is stored in this room it quickly becomes moldy and clumps if the chemical is powder and when there is a preparation activity the smell collects in the room even though we have followed the work procedure in the acid cabinet. Even though our activities have followed the procedure, because the circulation in the chemistry lab room only uses hexos, the air circulation is still not good."

Based on the distribution of perceptions regarding comfort criteria in the chemical laboratory, the researchers re-evaluated the sub-themes and consolidated them into a single overarching theme for laboratory comfort—thermal comfort (Table 3).

Table 3. Comfort Criteria for Chemistry Laboratory Spaces

Sub-Theme	Theme
Room temperature	Thermal Comfort
Air circulation	
Air humidity	
Smell	

Thermal comfort is a critical parameter that reflects an individual's perceptual and physiological response to environmental conditions, particularly in relation to ventilation efficiency. It plays a fundamental role in ensuring user satisfaction and well-being within an indoor space (Febiyani, 2020). The thermal comfort of an environment significantly influences health, cognitive performance, and overall productivity, as it is closely linked to the body's thermoregulation process. This balance is affected by ambient conditions during activities, representing a physiological adaptation to metabolic heat generation in order to maintain homeostasis (Kukus et al., 2009). Thermal comfort is inherently associated with thermal health, which is defined as a state of mental and physical well-being in response to environmental stimuli. It is shaped by both internal factors, such as metabolic activity and clothing insulation, and external variables, including air temperature, airflow velocity, radiant temperature, and humidity levels (Ratnasari & Asharhani, 2021).

Achieving optimal thermal comfort within buildings and enclosed spaces necessitates the careful integration of design strategies, particularly concerning temperature regulation. Effective air circulation systems must be implemented to maintain stable thermal conditions, encompassing air temperature control, humidity management, airflow dynamics, and appropriate indoor lighting (Aritama, 2023). The rate of air exchange within a confined space serves as a crucial determinant of subjective thermal comfort, influencing occupants' perception of air freshness and overall environmental quality. Ensuring efficient air renewal by optimizing ventilation design is essential for mitigating indoor air stagnation and improving occupant satisfaction (Maulianti et al., 2021).

Furthermore, the architectural layout and ventilation design must be aligned with principles of indoor air quality management to foster an environment conducive to thermal health. This includes the integration of advanced ventilation technologies and air purification systems to mitigate pollutants and maintain optimal thermal equilibrium (Murniati, 2018).

These findings underscore the necessity of a holistic approach to thermal comfort, wherein design interventions are tailored to address user-specific needs while adhering to established environmental health and safety standards. By prioritizing indoor air quality and ventilation efficiency, built environments can be optimized to enhance thermal comfort, minimize health risks, and promote sustainable indoor living conditions.

Ensuring indoor environmental comfort necessitates maintaining high air quality to prevent the onset of Sick Building Syndrome (SBS), which manifests in symptoms such as sneezing, itchy eyes, dizziness, headaches, nausea, nasal irritation, dry throat, dyspnea, general discomfort, mood disturbances, lack of motivation, and concentration issues (Mansor et al., 2024; Marlina et al., 2023; Surawattanasakul et al., 2022). The design of an effective air circulation system within indoor spaces, such as chemical laboratories, is crucial to establishing a well-prepared and healthy environmental quality, particularly in high-risk facilities (Ghaffarianhoseini et al., 2018; Wang et al., 2008). A comprehensive literature review highlights that SBS significantly impacts well-being and productivity, with indoor air quality identified as a primary contributing factor. Therefore, efforts to enhance air circulation quality serve as a necessary intervention to improve indoor air conditions, ultimately fostering a more comfortable and healthier environment (Niza et al., 2024).

Table 4. Specifications of Similar Chemical Laboratory Spaces

Products	Specification
Chemical Laboratory of Private University 1 – Testing Services	The testing services have been certified under ISO 17025:2014, providing learning, research, and testing services in the laboratory. The room remains cool even after 30 minutes of occupancy, with airflow supplied by Split-type Air Conditioners (AC). The laboratory has an approximate area of 90 m^2, equipped with eight AC units, each with a capacity of 2 PK. Indoor air is ventilated to the outside through a fume hood installed in the chemical storage cabinet. Users have reported concerns regarding humidity levels and air odor. Additionally, some users have expressed discomfort due to excessive cooling, leading to frequent urges to urinate when staying in the room for extended periods, which affects concentration.
Chemical Laboratory of Private University 2 – Testing Services	The testing services have not yet been certified under ISO 17025:2014 but provide learning, research, and testing services in the laboratory. The room remains warm even after 30 minutes of occupancy, with airflow supplied by a Central Air Conditioner (AC) system. The laboratory has an approximate area of 100 m^2, with eight AC distribution points. Indoor air is ventilated to the outside through a fume hood installed in the chemical storage cabinet and an exhaust fan. Users have reported concerns about the lack of cooling in the room. Additionally, some users have experienced discomfort, including eye irritation and feelings of thirst when engaged in prolonged activities inside the laboratory.

Benchmarking

The next step in Quality Function Deployment (QFD) involves the development of an improved air circulation system based on existing designs. The development analysis is conducted by examining several chemistry laboratories within the education sector that have expanded their services beyond education, including community service and research, to identify added value in the proposed air circulation system. A comparative analysis is performed between the air circulation systems of two chemistry laboratories in higher education institutions (HEIs) that serve as chemical testing service facilities, allowing for the identification of best practices and areas for optimization in air circulation management.

Based on the comparative analysis conducted, the regulation of air circulation systems to achieve thermal comfort is carried out by considering several comfort aspects, particularly temperature and air circulation within the indoor environment. The thermal comfort aspect of indoor temperature refers to air conditions that can be perceived by the human body during activities, resulting in a subjective response related to the perception of comfort. Meanwhile, the air circulation comfort aspect pertains to airflow conditions that maintain room humidity and ensure stability between the input and output of air within the indoor and outdoor environments. Efforts to enhance thermal comfort by optimizing air circulation can reduce health risk factors associated with Sick Building Syndrome (SBS), thereby improving work productivity within buildings or enclosed spaces (Niza et al., 2024). Interventions aimed at enhancing indoor productivity and preventing Sick Building Syndrome (SBS) can be implemented through the strategic planning of ventilation system designs, including mechanical ventilation, natural ventilation, air conditioning systems, and other related measures (Wang et al., 2022).

House of Quality (HoQ)

The House of Quality (HoQ) matrix provides a structured framework for analyzing the relationship between user requirements and technical specifications in optimizing air circulation systems within chemical laboratories. The analysis identifies four primary user needs: room temperature, air circulation, humidity levels, and indoor air quality (odor control). Among these, room temperature is the most critical factor influencing user comfort, underscoring the necessity for an efficient cooling system. The correlation between user requirements and technical specifications is assessed based on four key aspects: air cooling systems, air circulation pathways, air regulation mechanisms, and circulation points. The highest weight is assigned to air regulation mechanisms (36 points) and the number of circulation points (24 points), highlighting their pivotal role in ensuring optimal indoor air quality.

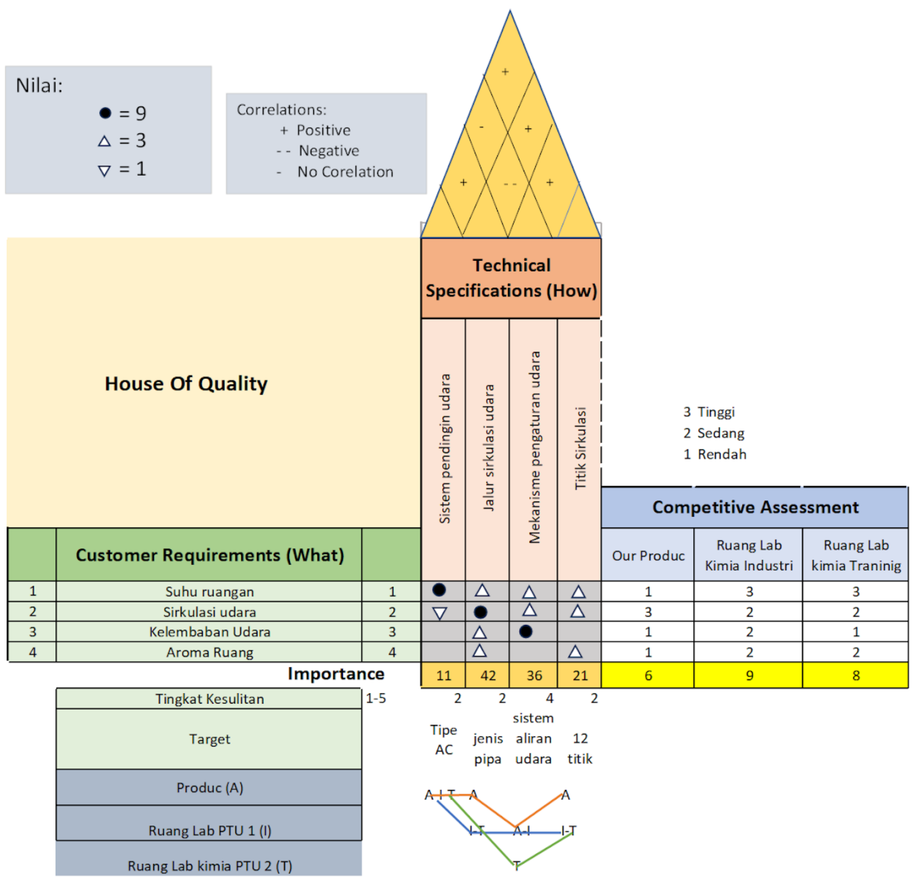

Figure 4. *House of Quality (HoQ) for the Air Circulation System in Educational Chemistry Laboratories*

A comparative assessment between the proposed system and two existing chemical laboratories—an industrial chemistry lab and a training chemistry lab—reveals significant differences. The industrial chemistry lab exhibits the highest air circulation efficiency (score: 9), followed closely by the training chemistry lab (score: 8), whereas the proposed system currently scores lower (6), indicating a need for further improvements, particularly in optimizing air distribution. The implementation complexity of the air circulation system is evaluated based on four parameters: air conditioning type, pipeline system, airflow mechanism, and air circulation points (12 identified points). Among these, the airflow mechanism presents the highest degree of complexity, necessitating careful planning to enhance efficiency.

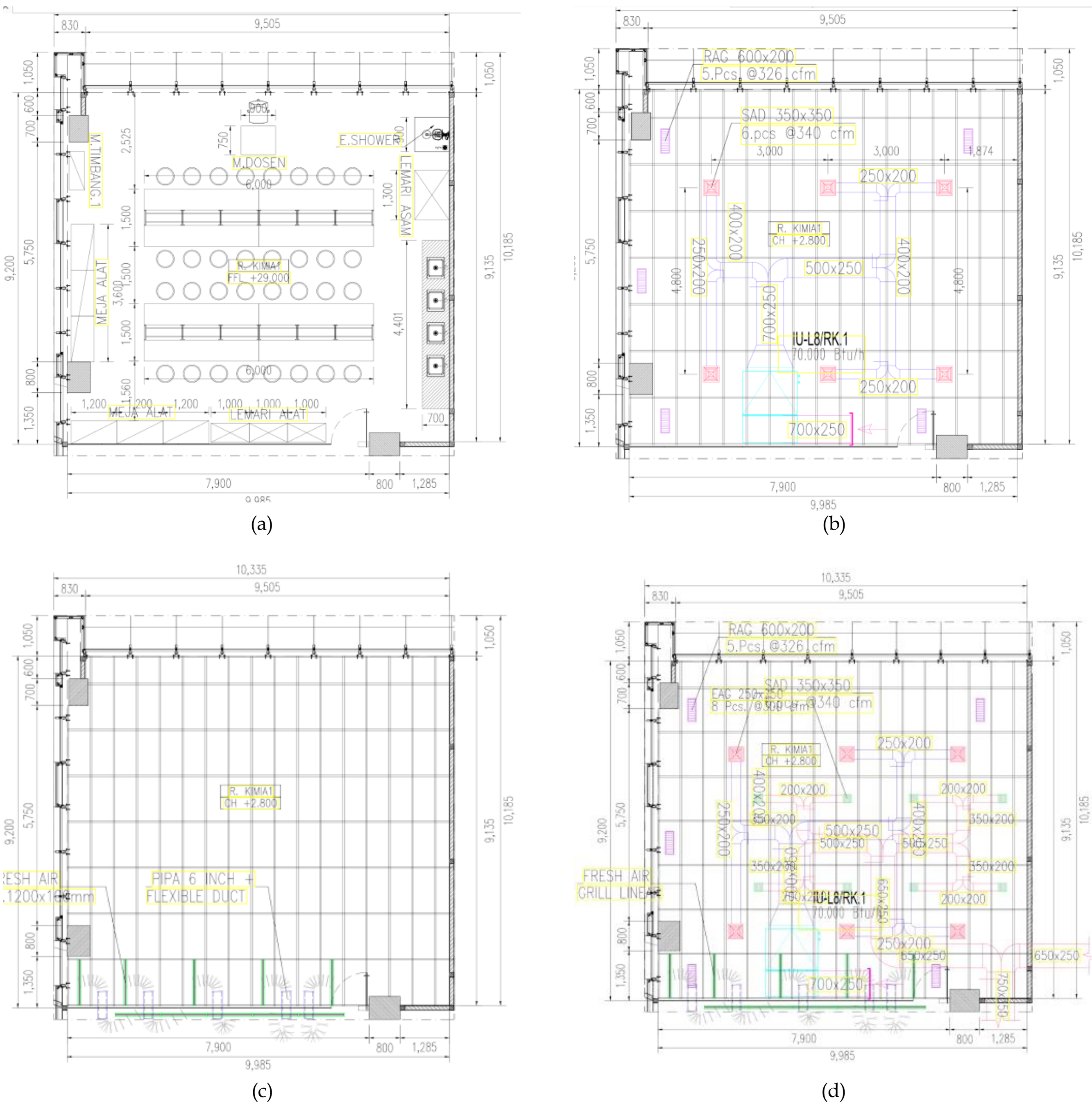

Figure 5. (a) Blueprint of the Chemistry Laboratory Design; (b) Air Conditioner Circulation Layout of the Chemistry Laboratory; (c) Fresh Air Circulation Layout of the Chemistry Laboratory; and (d) Design of Air Circulation System in the Chemistry Laboratory.

The findings underscore that temperature control and air circulation efficiency are the primary determinants of indoor air quality in chemical laboratories. The current system requires further refinements, particularly in expanding circulation points and enhancing air regulation mechanisms to achieve optimal performance. These insights serve as a foundation for developing an advanced air circulation system that not only meets safety and regulatory standards but also fosters a healthy, comfortable, and productive laboratory environment.

Air Circulation System Design

A chemistry laboratory is classified as a high-risk environment for health. Activities conducted within this space typically involve hazardous operations, including the handling of highly flammable, toxic, and strong-smelling chemicals, as well as the use of heat-generating equipment, all of which can contribute to the onset of Sick Building Syndrome (SBS). Therefore, the strategic design of the air circulation system is crucial for ensuring optimal thermal comfort (Figure 5a).

According to the HoC analysis, achieving optimal thermal comfort in laboratory environments requires a well-structured design that integrates key elements such as air conditioning systems, airflow pathways, air regulation mechanisms, and circulation points. The schematic presented in Figure 5b depicts the layout of a chemistry laboratory covering an area of 100 m², designed to accommodate up to 30 users. The estimated ratio of user space to total workspace is approximately 1:2.5 m². The layout is meticulously planned to incorporate essential infrastructure, including workbenches, sinks, emergency showers, and fume hoods. Among these components, the primary sources contributing to elevated humidity levels within the laboratory are the sink area and fume hoods, both of which introduce additional moisture into the indoor environment.

The regulation of air temperature and humidity in chemical laboratories (Figure 5c) is managed through the installation of an air conditioning system. For a room with an estimated size of 100 m² and a ceiling height of 3 meters, the cooling requirement is approximately 45,000 BTU/h. Consequently, a Ceiling Cassette air conditioning unit with a capacity of 4 PK is necessary to meet the cooling demands based on the Cooling Load method, particularly for classrooms and academic activity spaces (Bahantwelu & Mbake, 2022; Rachman et al., 2023). The Ceiling Cassette AC was selected due to its ability to distribute cool air evenly and efficiently, making it particularly effective in maintaining a stable and comfortable indoor temperature. A stable room temperature is essential in preventing Sick Building Syndrome (SBS) (Kang et al., 2021; Mansor et al., 2024). Additionally, the Ceiling Cassette AC is preferred for its relatively low noise levels, ranging from 25 dB to 50 dB. A quiet indoor environment, particularly in workspaces such as laboratories, has been shown to enhance comfort and productivity.

The air circulation system in Figure 5d is managed using the Louver Fresh Air (LFA) system. The implementation of LFA allows fresh outdoor air to enter the indoor space, improving air circulation quality and maintaining a healthier indoor environment (Bertolín et al., 2023). Consistently introducing fresh air into the laboratory reduces the concentration of airborne pollutants, including dust and chemical residues. The fresh air supplied through LFA also helps regulate indoor humidity levels, counteracting the excessive dryness caused by air conditioning or the high moisture content generated by frequent water usage within the space (Jia et al., 2024). The LFA system is designed with a single vertical channel directing airflow into the room, while the horizontal distribution is divided into six output points, each measuring 250 mm × 200 mm, covering an area of 1:14 m². Each LFA output point delivers airflow at a rate of 15–250 Cubic Feet per Minute (CFM). The airflow rate per minute (CFM) plays a crucial role in temperature and humidity control, directly influencing thermal comfort levels (Robinette, 2022). Proper humidity regulation significantly reduces SBS symptoms such as headaches, throat discomfort, and concentration difficulties (Mansor et al., 2024; Pourkiaei & Romain, 2023).

Conclusion

The study highlights that optimal air circulation is achieved through a combination of well-specified air conditioning systems, properly designed airflow pathways, balanced air distribution mechanisms, and the strategic placement of air circulation points. In particular, the integration of cassette-type air conditioning units with the Louver Fresh Air (LFA) system has proven effective in regulating thermal conditions while promoting continuous fresh air intake. This configuration not only improves indoor air quality but also plays a preventive role against Sick Building Syndrome (SBS) symptoms such as headaches, throat irritation, and reduced cognitive function. By enhancing user comfort and health, such systems contribute to improved concentration, reduced fatigue, and overall better performance in laboratory settings. These findings, while drawn from chemistry laboratory contexts, offer valuable insights for broader educational and institutional environments where enclosed indoor activities are conducted. The principles of thermal comfort and air quality management outlined in this study can be adapted to classrooms, computer labs, and other learning spaces that rely on air conditioning and mechanical ventilation. Practically, the research underscores the importance of investing in user-centered environmental design, especially in educational infrastructure planning. Institutions aiming to upgrade or construct laboratory facilities should consider thermal comfort as a core design criterion to foster healthier, safer, and more productive learning environments. This study provides a framework for integrating environmental ergonomics into the design of educational spaces, with the potential to reduce health complaints, increase user satisfaction, and support better academic outcomes.

Acknowledgments
The author team would like to thank all parties involved in this research so that it could be completed.

Author Contributions
This article was written by six authors, namely A, H. G., R. A. P., A. R. Y., D. E., and D. W. All authors worked together in carrying out the research and writing this article at every stage.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare that there are no conflicts of interest regarding the publication of this article.

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