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A study of a Smart Folding Chair for Welding Workshops in the Mechanical Engineering Department

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Abstract: The Smart Folding Chair is an innovative upgrade of the original *Classroom Folding Chair*, which was designed to address space limitations in welding workshops. The initial version introduced a foldable frame with wheels for improved space management in confined areas. However, it relied on a manual folding mechanism, which posed challenges in usability and convenience during frequent use. Additionally, the absence of smart features limits its relevance in modern learning environments. The main objectives of this project are to develop an automatic folding chair that can be controlled using a mobile phone, to optimize the physical effort and energy required for arranging and storing chairs in confined learning environments, and to build an electronic circuit system that automates the folding process using an Arduino microcontroller. These objectives aim to improve functionality, enhance user convenience, and support the implementation of smart technology in technical and vocational education settings. The methodology involved integrating an Arduino UNO with a Bluetooth module (HC-05) and motor system into the chair's frame. The system was programmed to respond to mobile commands for folding operation. The results showed that the upgraded chair successfully performed automated folding within seconds, improving efficiency, user convenience, and overall functionality. This version is more adaptable for use in technical workshops, classrooms, and multipurpose educational spaces. In conclusion, the Smart Folding Chair offers a practical, modern solution that supports Industry 4.0 by introducing automation into traditional furniture. As a recommendation, future developments should focus on improving battery efficiency, enhancing system durability, and exploring features such as solar charging and motion sensors to further increase functionality and sustainability.

Keywords: *Smart Folding Chair, Classroom Folding Chair, Welding Workshop, Foldable Chair*

1.0 INTRODUCTION

The development of the smart folding chair is an improvement of the classroom folding chair that have been design previously. The development of classroom folding chairs was carried out in the welding workshop to minimize the space used in the welding area. This innovation addresses the limitations of the existing design, particularly in welding areas where space is extremely limited and the environment is uncomfortable. The enhanced chair aims to support the implementation of EKSA (Public Sector Conducive Ecosystem) by promoting a more organized, ergonomic, and space-efficient workplace.

A Smart Folding Chair is an innovative seating solution designed to address the limitations of conventional chairs, especially in environments with limited space such as welding workshops. Traditional chairs are often bulky, heavy, and difficult to store, making them unsuitable for compact areas where flexibility and mobility are essential. This project builds upon a previously developed Classroom Folding Chair and introduces significant improvements in terms of design, functionality, and user convenience. A Smart Folding Chair features a lightweight and portable structure, equipped with wheels for easy movement and storage. A key innovation is the integration of an automatic folding mechanism controlled via the "Arduino Bluetooth Control" mobile application, reducing the need for manual effort. Inspired by the concept of automatic home doors, this system enhances user experience and efficiency. To support environmental sustainability, recycled materials are incorporated into the chair's seat, promoting responsible use of resources. With its foldable design, smart technology, and eco-friendly elements, the Smart Folding Chair is highly suitable for workshops, classrooms, study areas, and other multipurpose spaces requiring quick setup and efficient use of space.

2.0 LITERATURE REVIEW

In technical and vocational institutions such as polytechnics, welding workshops play a critical role in providing hands-on practical training. However, these environments often face limitations such as restricted space, safety hazards, and poor organization due to the bulky nature of welding equipment and fixed furniture arrangements (Ahmad & Hassan, 2020). These constraints hinder efficient workspace management and contradict the implementation of EKSA (Public Sector Conducive Ecosystem), which promotes a clean, organized, and systematic work environment (Jabatan Pendidikan Politeknik, 2021). To address space usage challenges during theory sessions before welding activities, the Classroom Folding Chair was developed in 2019. It was constructed from mild steel and featured a manual folding mechanism, allowing some flexibility and reducing floor occupancy (Zulkifli et al., 2019). However, despite its functional intentions, this chair posed several critical issues such as heavy weight, lack of mobility, and the need for physical effort during folding and storage. These drawbacks made it inefficient for dynamic learning spaces and incompatible with the smart learning goals emphasized by IR 4.0. Globally, the rise of smart furniture has been evident, particularly in administrative and healthcare environments. For example, smart office chairs are equipped with posture sensors and app-based control systems to improve ergonomic comfort (Chen et al., 2021), while automated wheelchairs utilize Arduino and Bluetooth technologies to facilitate remote mobility assistance (Singh & Rahman, 2020). However, such solutions often lack the portability, foldability, and ruggedness needed in technical workshop applications. To bridge this technological and functional gap, the Smart Folding Chair was introduced in 2024 as an enhanced prototype based on the original Classroom Folding Chair design.

This improved version integrates an automatic folding mechanism operated via the Arduino Bluetooth Control mobile app. A DC motor is controlled by the Arduino microcontroller, enabling remote folding and unfolding through smartphone commands, thus significantly reducing manual handling and improving operational efficiency. Additional improvements include a more portable structure with built-in wheels and the use of recycled materials in the seat design, promoting sustainability. These features not only ease physical strain but also support institutional goals toward a smarter, greener, and more adaptable learning environment. Ultimately, the Smart Folding Chair provides a comprehensive solution that addresses the shortcomings of the earlier design while aligning with EKSA practices and the demands of IR 4.0 education.

The ESP32 microcontroller is an ideal component for enhancing the functionality of the Smart Folding Chair. Developed by Espressif Systems, the ESP32 combines a powerful dual-core processor with integrated Wi-Fi and Bluetooth capabilities, making it highly suitable for smart automation projects such as this.In the Smart Folding Chair, the ESP32 replaces basic microcontrollers (like Arduino UNO) to provide a more efficient and flexible control system.

Its built-in Bluetooth allows users to send folding or unfolding commands via a mobile application, similar to how smart devices are used in home automation. When a command is received, the ESP32 activates a motor driver module that powers the DC motor responsible for folding or unfolding the chair. This process reduces the need for manual labor and improves the user experience, especially in space-constrained environments like welding workshops, classrooms, and training labs.

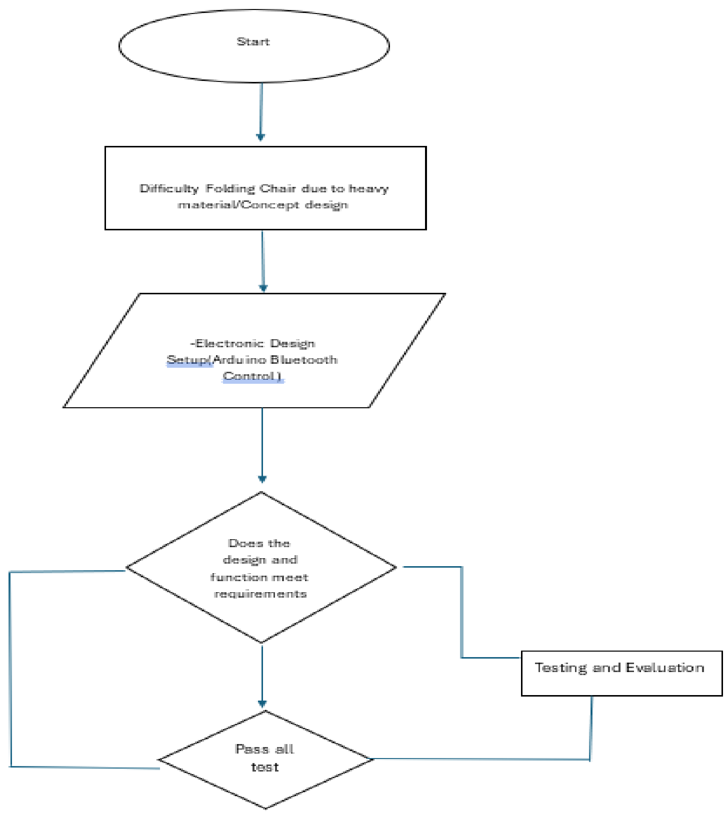
In the development of the Smart Folding Chair, a high-current motor driver is required to ensure the reliable and efficient operation of the automatic folding mechanism. The IBT-2 motor driver, also known as the BTS7960 H-bridge module, is utilized for this purpose. This driver is capable of handling up to 43A of continuous current, making it highly suitable for controlling powerful DC motors typically used in mechanical actuation systems.

In this project, the IBT-2 driver receives control signals from the ESP32 microcontroller via Bluetooth. Commands sent from a smartphone through the "Bluetooth Control" mobile application trigger the folding mechanism without requiring physical effort. The robust performance of the IBT-2 module ensures smooth and safe motor operation, even under load, and is a crucial component in transforming the chair from a manual system to a smart, automated solution aligned with Industry 4.0 and EKSA (Public Sector Conducive Ecosystem) principles.

3.0 METHODOLOGY

3.1 Transformation Design: From Classroom Folding Chair to Smart Folding Chair with Bluetooth Control Integration

The original *Classroom Folding Chair* was initially designed to solve space constraints in welding workshops. While it offered some benefits in terms of reducing floor usage, the design had several critical limitations that affected its practicality. One major issue was its inability to fold, causing it to occupy fixed space even when not in use. This made it difficult to optimize workshop layouts, especially in compact or shared environments. Additionally, the absence of mobility features such as wheels and the heavy structure made it cumbersome to move, rearrange, or store. These limitations impacted not only space management but also daily cleaning and workshop flexibility. Moreover, the chair lacked any technological integration, which made it incompatible with the demands of smart learning spaces. Without modern functionality, it did not support efficient use in environments advancing toward Industry 4.0 standards. User comfort was also a concern, as the earlier design did not consider ergonomic aspects, leading to discomfort during prolonged use in theory sessions or welding preparation.In response, the design was transformed into the Smart Folding Chair, which introduces a significant innovation: an automated folding mechanism controlled via Arduino Bluetooth Control. Users can now fold or unfold the chair remotely through a mobile application, greatly reducing physical strain and enabling quicker space adjustments. The Bluetooth-based system, inspired by automated door technologies, marks a transition from manual furniture to smart, user-responsive design.



Flow Chart 1: Smart classroom folding chair

3.2 Electronic Design Phase: Arduino Bluetooth Control System

The Smart Folding Chair incorporates an electronic automation system to enhance usability and reduce manual effort. At the core of this system is an Arduino UNO microcontroller, which enables the chair to fold or unfold automatically based on commands sent via a Bluetooth mobile application. This integration represents a major innovation from the original manual design, aligning the product with modern IR 4.0 practices.

3.3 Schematic Diagram Descriptions

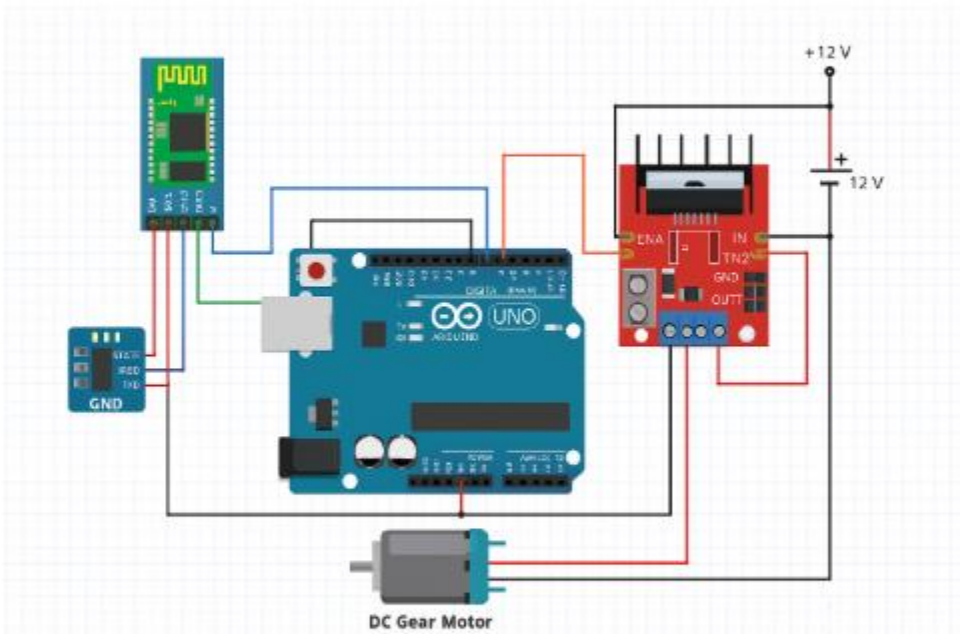


Figure 1: Schematic diagram of the Smart Folding Chair system

Figure 1 presents the schematic diagram of the Smart Folding Chair system, highlighting the integration of an Arduino-based (or ESP32-based) Bluetooth control system connected to the IBT-2 motor driver and a DC motor. Firstly, component-level testing is performed, where individual components such as the ESP32 microcontroller, IBT-2 motor driver, DC motor, and Bluetooth module are tested separately to confirm that each operates correctly. Next, system integration testing is carried out. During this phase, all components are assembled and tested as a complete system to ensure they work together effectively. The goal is to confirm that the system responds accurately to user inputs sent via Bluetooth, enabling the chair to fold and unfold smoothly.

4.0 DATA ANALYSIS AND FINDINGS

Based on the data illustrated in Figure 2, the Smart Folding Chair offers several advancements over the conventional classroom folding chair, particularly in terms of automation and user convenience. The folding mechanism of the smart chair is motorized and controlled via Bluetooth, eliminating the need for manual operation. This feature provides a hands-free solution, ideal for elderly or disabled users. In contrast, the traditional chair requires manual folding, which involves physical effort and time.

In terms of folding time, the Smart Folding Chair completes the action in just 3 to 4 seconds, compared to 8 to 10 seconds for a conventional chair. This is particularly beneficial in environments that require quick setup or frequent reconfiguration, such as classrooms or multipurpose halls.

The user effort is significantly reduced with the smart version. Controlled via a mobile application, users no longer need to manually bend or lift the chair, reducing physical strain and enhancing convenience. However, this added functionality contributes to increased weight, with the Smart Folding Chair weighing approximately 8 to 9 kg, while the conventional chair remains lighter, at around 6 to 7 kg. Despite the weight increase, the smart chair remains portable and practical due to its automation benefits. Another key difference is in the power requirement. The conventional chair functions independently of any power source, while the smart version requires a 12V DC power supply or battery to operate. This introduces a dependency on electricity, which must be managed in daily use. Lastly, regarding noise level, the traditional chair is silent during operation, whereas the Smart Folding Chair produces low mechanical noise from the DC motor. Although this noise is minimal, it is still suitable for indoor environments such as classrooms, where noise levels must be kept low.

In conclusion, the Smart Folding Chair presents a modern and user-friendly upgrade to traditional folding chairs. While it introduces some disadvantages, such as higher cost, increased weight, and power dependency, the improvements in efficiency, accessibility, and user comfort make it a valuable solution in educational and public use settings.

Criteria	Classroom Folding Chair	Smart Folding Chair	Analysis / Remarks
Folding Mechanism	Manual	Automated (Motorized via Bluetooth)	Hands-free operation; ideal for elderly/disabled users.
Folding Time (Average)	8–10 seconds (manual effort)	3–4 seconds (automated)	Folding time reduced by more than 50%.
User Effort	High (requires physical handling)	Low (controlled via mobile app)	Minimal strain; improved convenience and accessibility.
Weight	~6–7 kg	~8–9 kg (due to motor and electronics)	Slightly heavier; acceptable considering added functionality.
Power Source	Not required	Required (12V DC or battery-powered)	Power-dependent; needs charging or stable power supply.
Noise Level	Silent	Low mechanical noise from DC motor	Acceptable for indoor use; may not be ideal for ultra-quiet settings (e.g., library).

Figure 2: Comparison smart folding chair and a classroom folding chair

5.0 DISCUSSION AND CONCLUSIONS

5.1 Discussion

The development and implementation of the Smart Folding Chair demonstrate a significant improvement in functionality, convenience, and user interaction compared to the traditional Classroom Folding Chair. Based on the comparative data presented in Figure 2, several critical enhancements were achieved through the integration of automation and control systems.

One of the key differentiators is the automated folding mechanism, which replaces the need for manual handling. Controlled via a Bluetooth-enabled mobile interface, the Smart Folding Chair offers a hands-free operation, significantly reducing user effort. This is particularly beneficial for users with mobility issues, such as the elderly or those with physical limitations, making the design more inclusive and accessible.

From a performance perspective, the average folding time of the Smart Folding Chair is reduced to 3–4 seconds, compared to 8–10 seconds for the classroom folding chair. This efficiency contributes to faster setup and storage, which is especially valuable in environments such as schools, conference halls, or event spaces where large numbers of chairs are frequently moved or rearranged.

The trade-offs introduced by the smart design include increased weight (approximately 8–9 kg due to the addition of motors and electronics) and dependency on power sources. The need for a 12V DC supply or rechargeable battery may limit its application in areas without consistent electrical access. Furthermore, minor mechanical noise produced during motor operation could be a consideration in quieter settings. However, these disadvantages are manageable and acceptable when weighed against the benefits of automation, safety, and ease of use.

Additionally, while the cost of the Smart Folding Chair is higher than that of a traditional chair, the added value it provides in terms of automation, time-saving, and user-friendly operation justifies the investment, particularly in high-usage environments.

5.2 Conclusion

In conclusion, the Smart Folding Chair represents a technologically enhanced solution to traditional seating challenges in educational and multipurpose settings. It introduces modern engineering elements such as motorized systems and microcontroller-based control, resulting in a chair that is faster, safer, and easier to operate.

While there are limitations, such as cost, weight, and power dependence, the overall performance and functionality improvements position the Smart Folding Chair as a viable and innovative alternative to the conventional classroom folding chair. The chair meets its design objectives by enhancing efficiency, reducing physical strain, and aligning with smart automation trends in furniture.

The findings suggest strong potential for wider adoption, particularly in environments where frequent folding and unfolding are necessary. Future improvements could focus on reducing weight, integrating renewable power options (e.g., solar charging), and minimizing noise for quieter environments.

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