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Integration of Quality Function Deployment (QFD) and Ergonomic Work Posture Analysis to Redesign the Dyeing Table at Batik Mahkota Laweyan

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ABSTRACT

The traditional batik industry still depends on non-ergonomic tools, especially during the Colet dyeing process, which exposes artisans to significant musculoskeletal disorder (MSD) risks. Prolonged static postures, repetitive arm movements, and mismatched table heights cause discomfort in the back, shoulders, and neck, ultimately reducing productivity. This study aims to design an ergonomic workstation that enhances safety and comfort for batik workers through the integration of the Nordic Body Map (NBM), Rapid Entire Body Assessment (REBA), and Quality Function Deployment (QFD) approaches. Three workers from Batik Mahkota Laweyan participated in the research through questionnaires, observations, and interviews. NBM identified the colet process as the most discomfort-inducing activity, while the initial REBA score of 9 indicated a very high ergonomic risk. The QFD analysis translated workers' needs into specific technical criteria, such as adjustable height, tiltable surface, and lightweight materials, resulting in a redesigned dyeing table prototype. CATIA simulations validated the improvement, with the REBA score decreasing from 9 to 3, signifying a shift from high to low risk. The findings confirm that integrating ergonomic analysis tools with participatory design effectively reduces MSD risk and supports user-centered innovations in traditional craft industries. The study contributes theoretically by proposing a replicable framework that bridges ergonomic assessment and design application, and practically by providing a validated workstation design that improves comfort, health, and productivity. The novelty lies in the combined use of NBM, REBA, and QFD within a single methodological framework, an approach rarely applied in the traditional batik sector, demonstrating how systematic ergonomic integration can modernize artisanal practices while preserving cultural craftsmanship.

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1. Introduction

The procedure of making batik is crucial for judging the fabric's overall quality and beauty. The phase of Colet dyeing is quite important. Batik coloring with the Colet technique involves applying color to the batik motif by smearing or painting a color solution onto the cloth, using tools such as brushes or rattan tools. This technique allows workers to produce batik with rich details and color

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gradations. But the standard workstations used in this process are not usually designed for comfort, which could cause strain and musculoskeletal disorders (MSDs). Most dyeing tables are simple, fixed-height structures that are about 70 to 80 cm tall and have flat, wide surfaces that don't fit all of the different body types of workers (Daruis et al., 2024).

Preliminary evaluations at the Batik Mahkota Laweyan in Surakarta confirmed multiple reports of discomfort and pain in the back, shoulders, and neck during prolonged working hours, underscoring the urgent need for ergonomic interventions (Aranti et al., 2024). Traditional batik-making involves inappropriate work postures and repetitive movements, posing potential health risks for workers (Putri et al., 2024). Previous attempts to improve comfort, such as changing the seating configurations and screen angles, have not worked very well since they do not address the main problem of workstation design. It is beneficial to incorporate ergonomic principles into the design of batik dyeing tables, since this allows for posture modification and accommodates individuals of diverse sizes (Choirunnisa & Muslimah, 2025; Novalesi et al., 2025). Using adjustable, well-designed desks, people can work in neutral positions, which can help them feel better, work more efficiently, and be more productive over time. Data from similar craft industries shows that ergonomic changes can greatly lower the number of musculoskeletal disorders (MSDs) and improve overall performance (Sahu et al., 2023). In other research says that redesigning work facilities and postures in the batik cap industry can reduce workers' muscle injury risk, especially in the back, neck, elbow, forearm, and hands (Pratiwi & Nuriati, 2022). To protect the health of workers and keep the quality of work and productivity high in Indonesia's traditional batik industry, it is necessary to make a conscious effort to build an ergonomically optimised batik dyeing table (Aranti et al., 2024; Daruis et al., 2024).

The table is at a height that does not match the worker's anthropometry and requires a continuous bending posture Fig. 1, and Fig. 2, which aligns with findings on fatigue related to body posture.

Fig. 1. *Colet* dyeing work posture

Fig. 2. Height of the colet dyeing table

Although ergonomic tools such as the Nordic Body Map (NBM) and Rapid Entire Body Assessment (REBA) are widely used to identify posture-related risks, and Quality Function Deployment (QFD) is well established for translating user needs into design requirements, most studies apply these methods separately. Prior research has shown benefits when each tool is used individually, but the lack of integration often creates gaps between identifying ergonomic problems and implementing practical design solutions. Combining these approaches into a single framework remains a challenge. NBM and REBA serve as critical metrics for assessing ergonomic risks associated with various work postures and movements. NBM is particularly effective in illustrating the connection between specific postural strains and the symptoms experienced by workers (Setiawan et al., 2025). Likewise, REBA accounts for the musculoskeletal strain experienced by the entire body, offering a comprehensive risk assessment that can inform subsequent design modifications (Altintaş & Babaoğlu, 2025; Bora et al., 2025). Incorporating QFD into this assessment enables a systematic translation of identified user needs and preferences into design specifications, facilitating a more user-focused approach to creating ergonomic solutions (Hering & Schloske, 2022; Siwiec et al., 2023).

This study addresses that gap by combining NBM, REBA, and QFD in a single integrated methodology (Chen et al., 2022; Kulcsar et al., 2022). The novelty of this research lies in bridging the gap between identifying ergonomic problems and developing effective, user-centered design solutions supported by digital modeling for validation. Unlike previous studies that examined these tools in isolation, we demonstrate how their integration can generate an ergonomic workstation tailored for batik colet dyeing (Keshvarparast et al., 2024; Liu et al., 2024). The contribution of the research is twofold: theoretically, we advance ergonomic design methodology through a replicable integration framework; practically, we provide a validated workstation design that can improve comfort and reduce risks in traditional batik workshops. Current literature recognizes the limitations inherent in applying these tools in isolation, as they each provide valuable insights yet fail to address the holistic nature of ergonomic design (Celik et al., 2025; Mackey, 2024).

Such an integrated approach not only streamlines the risk assessment process but also enhances the effectiveness of ergonomic interventions (Alipour et al., 2021). Studies have indicated that workplaces designed with a thorough understanding of ergonomic principles substantially reduce the incidence of musculoskeletal disorders (MSDs), directly correlating to increased worker comfort and productivity (Budiyanto et al., 2024; Susihono & Adiatmika, 2021). This is particularly applicable in settings such as traditional batik workshops, where specific ergonomic considerations must account for unique operational demands (Ben-Bassat et al., 2021; Zhang et al., 2022).

Moreover, the validation of workstation designs through digital modeling and simulated user interactions represents a forward step in ergonomic design methodology. The ability to assess and modify designs in a virtual environment allows for iterative refinements that address ergonomic risks proactively (Altintaş & Babaoglu, 2025). This methodology has been echoed in research emphasizing the growing importance of adaptive technologies in ergonomics, particularly for traditionally manual processes like batik dyeing (Irminanda & Xiong, 2025; Kamala et al., 2025). In conclusion, this study proposes a novel framework combining NBM, REBA, and QFD to create a replicable methodology for ergonomic workstation design. The integration of these tools not only strengthens the theoretical foundation of ergonomic research but also contributes yields practical solutions that can significantly enhance worker safety and comfort in environments like traditional batik workshops, thereby addressing a critical gap in the existing literature (Kamala et al., 2025; Louzan et al., 2025).

2. Method

This study used an integrated ergonomic approach. It combined the Nordic Body Map (NBM) and Rapid Entire Body Assessment (REBA) methods with a qualitative design process based on Quality Function Deployment (QFD). This framework systematically identified musculoskeletal problems and analyzed posture-related risks. It also translated workers' real needs and experiences into technical design solutions for a more ergonomic batik colet workstation.

Fig. 3, presents the research stages, showing the process from problem identification to design validation. The study involved batik workers in several production stages: pattern design, canting (wax application), wax removal, dyeing, and drying. This research focused on the coloring (Colet) stage. This process requires high precision and long periods of static posture. At the Batik Mahkota Laweyan workshop, only three workers handled this stage, so all were included as research participants. Using total population sampling ensured every worker in the colet process was represented, allowing a complete understanding of their ergonomic conditions.

Despite the small number of participants, this approach is suitable for focused ergonomic studies. The goal is not statistical generalization but a deep, contextual understanding of posture and work behavior. The small and homogeneous group allowed comprehensive observation of each worker's patterns in real conditions. Qualitative research, as noted by Thapa et al., (2023), prioritizes depth over breadth, emphasizing detailed insights over large sample sizes. This aligns with ergonomic investigations that focus on specific human–work interactions. Primary data were collected from NBM questionnaires to identify discomfort, REBA-based posture documentation to assess risk, and interviews that captured workers' voices, needs, and expectations. Secondary data included literature on Indonesian anthropometric standards, ergonomic design principles, and previous studies on batik production. To strengthen data validity, methodological triangulation cross-verified observations, self-reported complaints, and interviews. This ensured conclusions reflected the workers' true experiences and conditions (Baral et al., 2022; Subedi, 2025).

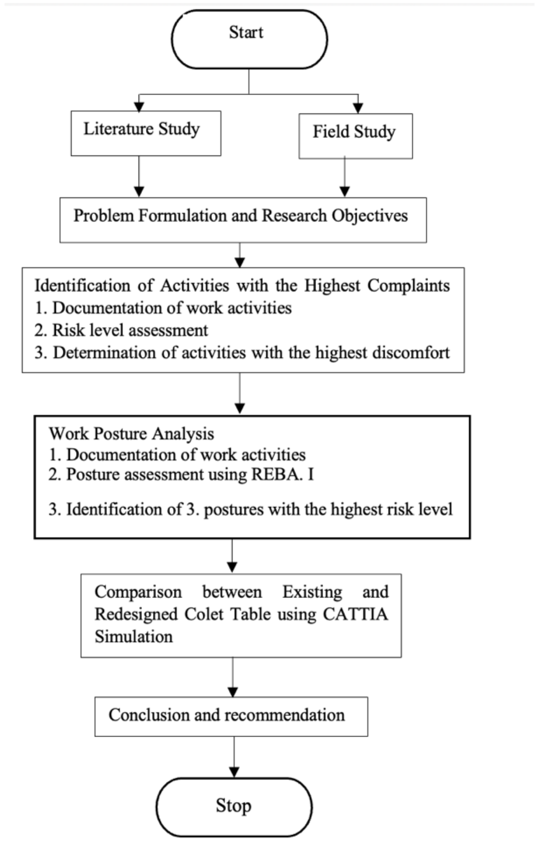


Fig. 3. Research Methodology Flowchart. The study involved batik workers in several production stages: pattern design, canting (wax application), wax removal, dyeing, and drying

3. Results and Discussion

3.1. Nordic Body Map (NBM) Analysis

The Nordic Body Map (NBM) method identified and quantified physical discomfort among batik workers, with a focus on the colet dyeing process at Batik Mahkota Laweyan. This approach systematically evaluates body areas prone to pain, fatigue, or strain from specific work postures and repetitive motions. The NBM questionnaire covers 27 anatomical points on the neck, shoulders, back, arms, waist, and lower limbs.

Data were collected from three workers, all of whom were actively involved in the colet dyeing process. They represent the entire manual dyeing team, providing a comprehensive view of ergonomic challenges in real-world conditions. Each worker completed an NBM self-assessment at the end of a full work session. Field observations and interviews helped validate self-reported discomfort. The analysis revealed that workers frequently experienced pain and stiffness in the neck, shoulders, back, and waist, particularly due to the prolonged forward-leaning postures required for precise dyeing. Fig. 4 shows the position of workers when process the dyeing activities.

As seen in Fig. 5 illustrates the average NBM discomfort scores across different stages of batik production. As shown, the *colet* dyeing process had the highest overall discomfort score (65.67), significantly higher than other activities such as pattern design, canting (drawing), wax removal, and drying. The highest pain levels were concentrated in the back (95%), waist (95%), and shoulders (88%), indicating prolonged static postures and repetitive arm elevation during dyeing process.

Fig. 4. Working posture of the dyeing process

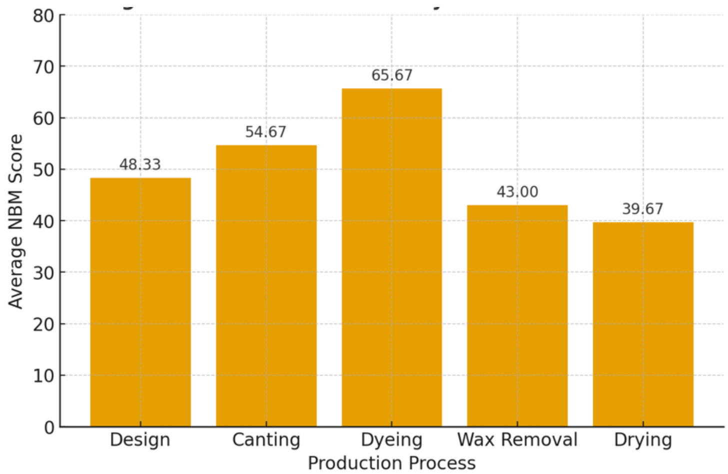


Fig. 5. Average Percentage NBM Score

Kanniappan and Palani highlighted that prolonged static postures can lead to significant musculoskeletal disorders (MSDs), reinforcing the notion that improper workstation design exacerbates these risks (Kanniappan & Palani, 2020). Similar ergonomic issues, such as lower back pain, are prevalent in occupations where static and awkward postures are commonplace, including traditional weaving (Ruliati et al., 2023).

3.2. Rapid Entire Body Assessment (REBA) Analysis

Rapid Entire Body Assessment (REBA) evaluated posture and ergonomic risks in the Colet dyeing process at Batik Mahkota Laweyan. The analysis used observational data and digital posture simulation through CATIA software. This allowed precise joint angle measurements and posture classification according to the REBA framework.

These findings, gathered through both observation and digital simulation, indicate that workers performing the colet process adopt a highly static working posture for extended periods, often exceeding 60 minutes without significant variation in movement. The low, flat work surface in the workshop requires workers to lean their trunks forward to maintain visual precision.

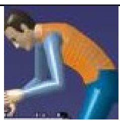
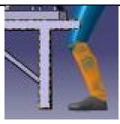
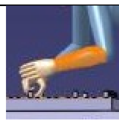
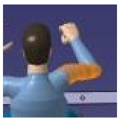
The Rapid Entire Body Assessment (REBA) was conducted to evaluate the posture and ergonomic risks associated with the Colet dyeing process at Batik Mahkota Laweyan. The analysis combined observational data and digital posture simulation using CATIA software, which allowed for precise measurement of joint angles and posture classification according to the REBA framework.

Observations revealed that workers performing the Colet process adopt a highly static working posture for extended periods, often exceeding 60 minutes without significant variation in movement. The work surface in the workshop is low and flat, requiring workers to lean their trunks forward to maintain visual precision.

Fig. 6. Working posture of the initial design

Fig. 6, shows that the neck remains flexed downward to focus on the motif, while the shoulders are elevated and abducted to reach across the work area. One arm often performs repetitive fine motor tasks, whereas the other supports body balance, resulting in asymmetrical loading. The legs and lower back bear the body's static weight, and the absence of adjustable seating or table height restricts postural variation. These findings indicate that the workstation does not accommodate the anthropometric diversity of workers, forcing them to adapt their body posture to the equipment rather than the other way around. As a result, discomfort accumulates in the neck, shoulders, back, and waist areas that correspond to the high discomfort regions identified in the NBM assessment.

Table 1. Summary of working posture degrees for initial design

Body Segment								
Neck	**Back**	**Legs**	**Shoulder**		**Elbow**		**Wrist**	
			Right	**Left**	**Right**	**Left**	**Right**	**Left**
 Flexion 10°	 Flexion 56°	 Flexion 40° & weight-bearing leg	 Flexion 65°	 Flexion 60°	 Flexion 70°	 Flexion 90°	 Extension 20°	 Extension 0°
			 Abduction 15°	 Abduction 10°				
			 Medial Rotation 15°					

The Colet dyeing process may cause certain body parts to remain static for over one minute, particularly the legs, which support the worker's body weight. Additionally, brush application involves repetitive motions exceeding four cycles per minute. This activity does not require tools with heavy handles or significant weight loads. Fig. 7, presents the results of the REBA analysis conducted during these procedures.

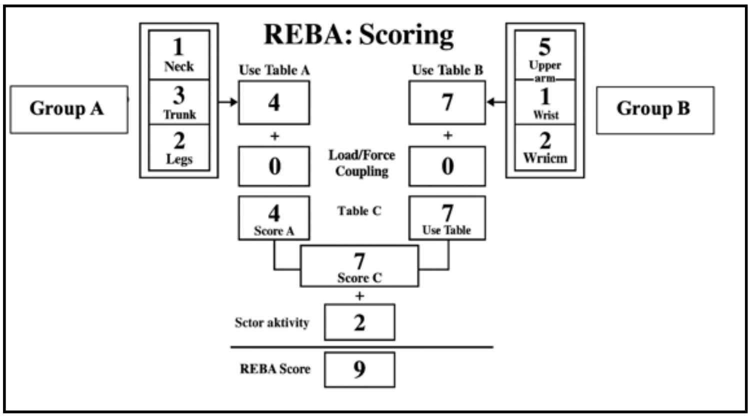


Fig. 7. REBA score of initial design

The analysis of the Colet process using the Rapid Entire Body Assessment (REBA) yielded a score of 9, categorizing it as high risk for musculoskeletal disorders (MSDs). This score is influenced by excessive trunk and neck flexion, prolonged shoulder elevation, and static postures held for extended periods, which can lead to cumulative strain on the neck, shoulders, back, and lower back. These findings are consistent with existing literature that emphasizes the importance of ergonomic assessments in reducing occupational injuries.

Table 2. Ergonomic Improvement Aspects

No	Problem	Improvement
1	Worker bends forward excessively (>60°) with raised shoulders	Adjust table height to match elbow level
2	Excessive arm reach	Match table surface dimensions to fabric size
3	Rigid and static posture	Implement adjustable table for sitting or standing positions
4	Non neutral hand position when holding dyeing tools	Use strong, smooth table material allowing neutral hand positioning or resting

Kraemer et al. reported that sustained forward head posture and neck flexion can lead to static overload on neck and shoulder muscles, thereby increasing the incidence of discomfort and pain (Kraemer et al., 2020). Similarly, found a significant correlation between body posture and the prevalence of musculoskeletal complaints among batik workers, indicating that posture-related risks are substantial contributors to discomfort in this field (Daruis et al., 2024). As seen in Table 2, the collective findings also suggest that prolonged arm elevation and trunk bending can increase spinal compression and overload muscular structures, potentially resulting in discomfort and fatigue. This participatory approach not only fosters a better understanding of ergonomic principles among workers but also supports greater productivity and a decrease in the prevalence of MSDs. In addressing ergonomic interventions, it is critical to involve workers actively in the process, as highlighted by Rostami et al. (Rostami et al., 2021). In summary, the high discomfort scores in the Colet activity underscore the urgent need for ergonomic interventions that take into account the specific postural demands faced by batik workers. The combination of excessive postures and repetitive fine motor tasks necessitates a redesign of the workstation to enhance comfort and reduce the risk of injury.

3.3. Quality Function Deployment Analysis

The REBA analysis revealed that prolonged bending and static upper-body postures during the dyeing process in textile manufacturing can lead to significant musculoskeletal strain among workers. Such findings underscore the vital role of ergonomic assessments in identifying risks that could compromise health and productivity (Imamoglu & Esi, 2024). The transition from the analysis to the Quality Function Deployment (QFD) phase is crucial, as it converts identified ergonomic risks into measurable user needs and technical design parameters, thereby improving workstation design (Sakinala et al., 2024). The integration of ergonomic principles facilitates enhanced comfort and safety while optimizing efficiency in daily tasks (Sauk & Uğurlutepe, 2023). For instance, effective design modifications based on ergonomic insights are essential for industries prone to high injury rates, such as textile manufacturing, where nonergonomic postures are prevalent (Kumar & Thangavelu, 2024).

During the Quality Function Deployment (QFD) phase, workers' perspectives shaped ergonomic design priorities for the Colet workstation. Through semi-structured interviews, they identified challenges with table height, surface tilt, stability, and ease of movement. These insights were converted into quantifiable attributes using the House of Quality (HoQ) framework, linking user needs with technical specifications such as height-adjustable mechanisms, tiltable surfaces, lightweight materials, and stability. Fig. 8 illustrates the ergonomic features that were most prioritized based on worker feedback.

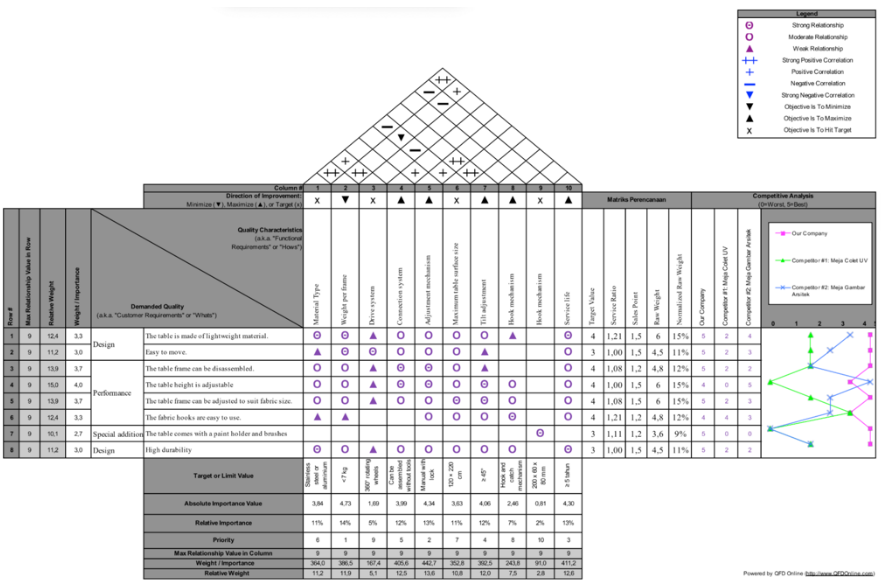


Fig. 8. House of Quality. Matrix indicated that adjustable table height, robust construction, and tilting mechanisms substantially influence worker comfort, safety, and operational efficiency during the dyeing process

The final House of Quality (HoQ) matrix indicated that adjustable table height, robust construction, and tilting mechanisms substantially influence worker comfort, safety, and operational efficiency during the dyeing process. This approach illustrates how Quality Function Deployment (QFD) enables the integration of ergonomic analysis with design innovation in traditional crafts such as batik by emphasizing the practical needs of workers rather than relying solely on theoretical models. Incorporating user feedback enhances product usability and mitigates the risk of musculoskeletal strain, thereby increasing productivity and worker satisfaction.

To assess the originality and effectiveness of the ergonomic *colet* dyeing table developed using the Quality Function Deployment (QFD) methodology, a comparative analysis was performed with two previously documented workstation models: the Architect Drawing Table and the UV Dyeing

Table (Amalia et al., 2023; Waspadatedja et al., 2022). This analysis benchmarks the proposed design against established alternatives regarding ergonomic performance, structural flexibility, and user-focused outcomes. The process of identifying worker requirements through QFD is further clarified by evaluating desk designs from prior studies (Zafriana et al., 2024). As seen in Table 3, summarizes the comparative features of these earlier table designs.

The results highlight the superior ergonomic and functional characteristics of the QFD-based Colet table. The new design features an adjustable height (40–110 cm) and a tiltable surface that can be adjusted up to 45°. These allow workers to maintain neutral working postures and substantially reduce musculoskeletal strain in the neck, shoulders, and lower back. The lightweight frame, constructed from stainless steel or aluminium (<7 kg), offers a balance between strength and portability. Mobility is enhanced by 360° swivel wheels, and a tool-free assembly system enables easy setup and takedown. Additional elements, such as the integrated paint container and spring clamp mechanism, simplify the workflow, improving both efficiency and usability.

Table 3. Competitor Product Specifications

Specifications	Product Name		
	Dyeing *Colet* Table	**UV Dyeing Table**	**Architect Drawing Table**
Type of material	Stainless steel or aluminum	Hollow dan aluminum	Iron with duco coating
Weight per frame	<7 kg	>5 kg	<19 kg
Drive system	360° rotating wheels	Stable without drive	Stable without drive
Connection system	Tool-free assembly	Must be assembled with tools	Must be assembled with tools
Regulatory mechanism	Manual with locking	Not adjustable	Turning the lever
Maximum size of table surface	120 × 220 cm	122 × 225 cm	90 × 120 cm
Tilt adjuster	≥ 45°	Not adjustable	≥ 45°
Hook mechanism	Spring clamp	Spring clamp	Paperclip
Paint container size	200 × 60 × 80 mm	-	-
Lifespan	≥ 5 years	≥ 1 years	≥ 1 years

Furthermore, the proposed table demonstrates an extended service life of more than five years, significantly longer than previous models, which typically lasted around one year. This ensures greater sustainability and long-term usability in workshop environments. Collectively, these findings confirm that the QFD-driven design process effectively translated workers expressed needs into measurable engineering parameters. As a result, the workstation combines practicality, comfort, and durability. The detailed transformation of customer requirements into technical specifications is summarized in Table 1.

The conversion of client requirements derived from the QFD (Quality Function Deployment) process into particular design implementations is shown in Table 4. To ensure that the ergonomic needs of the colet workstation were adequately met in the finished prototype, every characteristic of the House of Quality (HoQ), a matrix for correlating customer requirements to design features, was translated into quantifiable design elements.

Table 4. Application of QFD Results to Design

QFD Result Parameters	Design Implementation
Material type Stainless steel or aluminum	All parts except wheels
Weight per frame <7 kg	Cylindrical frame and tool place (except side pole frame because it is equipped with driving wheels)
360° rotating wheel drive system	Wheels
Connection system is easy to assemble without tools	Assembly rangka side pole, silinder, dan tools place
Manual adjustment mechanism with lock	Screw adjustable
Maximum size of table surface 120 × 220 cm	Long and short cylinders
Tilt regulator ≥ 45°	No strict communication with hinge
Fabric hook mechanism in the form of a spring clamp	Silinder
Paint container size 200 × 60 × 80 mm	Tools place
Lifespan ≥ 5 years	All parts

The QFD results clearly show how technical design solutions were methodically developed to meet user needs. Aluminium or stainless-steel frames weighing less than 7 kg enhance mobility while maintaining structural integrity. 360° rotating wheels and a tool-free assembly method offer flexibility and efficiency during setup. Screw and hinge systems enable adjustable height and tilt, allowing workers to modify their posture and reduce musculoskeletal strain. Practical features, such as the integrated paint bottle and spring clamp for fabric holding, help organize the workflow. Overall, these design choices combine ergonomic principles with user-cantered concerns, producing a colet table that is practical and comfortable to use in initial workshop settings.

3.4. Redesign of the olet dyeing table

Anthropometric data were used in the design to make sure the modified Colet dyeing table fits the users' bodies. The team chose elbow height, arm reach, and hand width because these factors are crucial for how people use their arms and reach their workspace. Data came from an Indonesian adult database and were adjusted to cover both very small and very large people, making the table suitable for almost everyone. Table 5 presents the measurements used to determine the optimal table height, tilt, and workspace layout for ergonomic use.

Table 5. Anthropometric data

No	Anthropometric Parameters	5th Percentile (cm)	95th Percentile (cm)
1	Elbow sitting height	57	70
2	Standing elbow height	92	108
3	Forward arm reach range	63	85
4	Hand reach range to the side	116	147
5	Hand width	8	10

Based on Table 5, the dimensions of the dyeing coloring table are determined as follows:

1. The height of the table can be adjusted to 40-110 cm so that it can be used in sitting and standing conditions. It is taken from the anthropometric parameters of the 5th percentile sitting elbow height and the 95th percentile standing elbow height.
2. The width of the table surface is adjustable between 100 and 120 cm, considering the width of the batik cloth, which is 119 cm, and the parameters of the hand reach range to the side.
3. The length of the table surface is adjustable, with a size of 100-220 cm.
4. Height adjusters or levers at least 5 cm in diameter to adjust the hand-held size.

The Colet dyeing table was designed according to the results of the QFD analysis with the help of SolidWorks software. Solid Works is an engineering software for creating 3D models. The new design is shown in Fig. 9.

Fig. 9. Redesign of the Colet dyeing Table

3.5. Work posture analysis for redesign the Colet dyeing table

To verify ergonomic improvements from the redesign, we analysed working postures with the new Colet dyeing table. The redesigned workstation Fig. 10, was evaluated using the Rapid Entire Body Assessment (REBA) method. This approach measured postural angles and identified risks of musculoskeletal disorders. Table 6, summarizes body segment positions and angles observed during the dyeing process. It illustrates the natural alignment of major joints, including the neck, back, shoulders, elbows, and wrists.

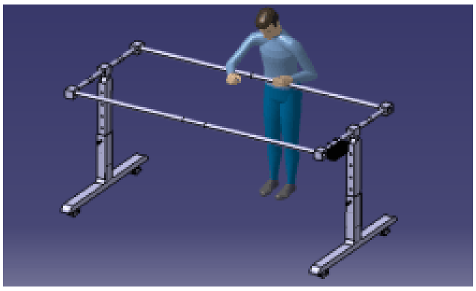
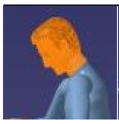
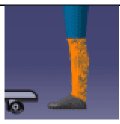
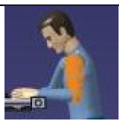
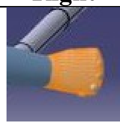
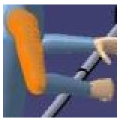
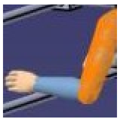


Fig. 10. Working Posture with redesigned table

The results show clear improvements in working posture compared to the previous table design. Neck flexion decreased to 8°, and the back maintained a stable position with only 15° of forward bending. Shoulder elevation was reduced to within a comfortable range of 20–45°, helping to ease tension in the upper body. The wrists moved symmetrically (95° flexion) with moderate elbow angles, indicating better balance and reduced muscle strain. During the dyeing process, workers could rest their lower limbs for support while using lightweight tools with minimal effort, thereby creating a more relaxed and sustainable work rhythm.

Table 6. Recapitulation of New Design Work Posture Degrees

Body Segment								
Neck	Back	Legs	Shoulder		Elbow		Wrist	
			Right	Left	Right	Left	Right	Left
 Flexion 8°	 Flexion 15°	 weight-bearing leg	 Flexion 45°	 Flexion 20°	 Flexion 95°	 Flexion 95°	 Extension 15°	 Extension 5°
			 Abduction 40°	 Abduction 30°				
			 Arm rest	 Arm rest				
			 Medial Rotation 50°					

Based on the REBA analysis Fig. 11, the redesigned table achieved a final score of 3, which falls under the low-risk category. This confirms that the new design successfully reduces postural stress and makes the working process safer and more comfortable. In practice, the redesigned table allows batik workers to maintain a more natural posture, work with less fatigue, and improve efficiency. Beyond its technical aspects, the table reflects a deeper goal of ergonomic design to create a workspace that not only supports productivity but also respects the human body and the craft behind it.

Effective wrist positioning and moderate elbow angles are crucial for reducing upper-limb tension, aligning with findings in other handicraft studies. While a final REBA score reference of 3 was mentioned as indicative of a low-risk ergonomic environment, it's important to verify such scores against normative data for specific occupations, which was not provided in the references. Ultimately, these improvements reinforce the role of ergonomic interventions in mitigating risks related to prolonged and repetitive tasks, although data supporting specific outcomes for batik workers is still emerging. These findings are consistent with the results of the present study, where the redesigned *colet* table featuring adjustable height and tilt functions proved effective in achieving a low REBA score and promoting greater ergonomic comfort (Astuti et al., 2022). Collectively, both studies highlight how adaptive workstation designs that accommodate user anthropometry can substantially enhance occupational well-being and support sustainable productivity in craft-based industries such as batik production.

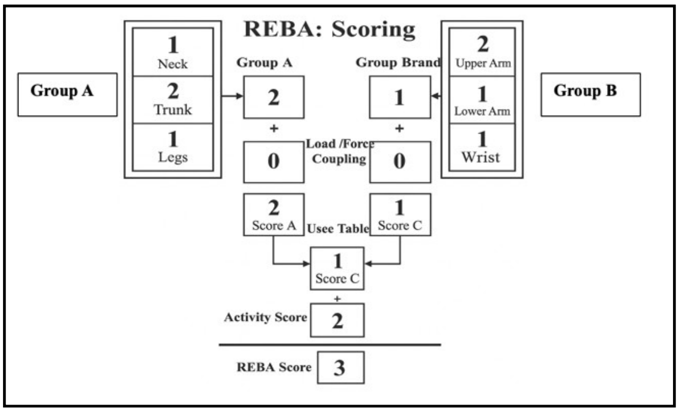


Fig. 11. REBA assessment for new design Colet table

4. Conclusion

This study demonstrates that the integration of ergonomic analysis and user-centered design can significantly enhance the safety, comfort, and productivity of traditional batik artisans. By combining the Nordic Body Map (NBM), Rapid Entire Body Assessment (REBA), and Quality Function Deployment (QFD) methods, this research establishes a systematic yet human-oriented framework for redesigning the Colet dyeing workstation. The findings revealed that artisans at Batik Mahkota Laweyan frequently experienced discomfort in the neck, shoulders, and lower back due to prolonged and awkward postures during the dyeing process. Through NBM and REBA, these critical problem areas were clearly identified and subsequently translated into technical design specifications using the QFD framework, ensuring that the redesign directly reflected workers' needs and feedback. The proposed ergonomic table, featuring adjustable height, a tiltable surface, lightweight materials, and enhanced mobility, effectively reduced ergonomic risks. Validation through CATIA simulation confirmed a substantial improvement, with the REBA score decreasing from 9 (high risk) to 3 (low risk). These results highlight that integrating empirical ergonomic assessments with participatory design principles not only mitigates musculoskeletal disorder (MSD) risks but also fosters user engagement and satisfaction. Beyond its technical achievement, the redesigned workstation symbolizes a shift toward more humane and sustainable practices in traditional craft industries.

Future research should expand on this integrated framework by involving a larger and more diverse sample of artisans to ensure broader applicability across various batik production settings. Further investigations could also explore digital human modeling, biomechanical load analysis, or longitudinal studies to evaluate long-term health outcomes and productivity impacts. Additionally, integrating environmental and economic factors into ergonomic design could support the development of comprehensive, sustainable solutions for traditional industries adapting to modern standards.

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