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Design of Workstation by Applying Ergonomic Principles

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Abstract

This study examines the ergonomic suitability of the classroom bench–desk system used at Rajshahi University of Engineering & Technology by comparing its dimensions with anthropometric data collected from 225 students. Eleven body measurements were analyzed to determine the 5th and 95th percentile limits, which were then used to derive acceptable ranges for key workstation dimensions through established ergonomic equations. A mismatch analysis revealed deficiencies in seat depth, backrest height, desk height, and seat width relative to students' physical characteristics. Based on these findings, an improved workstation design was developed and modelled in a Computer Aided Design software, incorporating corrected dimensions while maintaining functional workspace requirements for engineering tasks. The redesigned workstation is expected to enhance posture, comfort, and overall usability for the student population.

Keywords
Ergonomics, Anthropometric Dimensions, Workstation Design, Seat-Desk Interface, Classroom Furniture

1. Introduction
University students spend long hours sitting in lecture halls, laboratories, and study areas, which makes classroom furniture a critical factor in both health and learning outcomes. Poorly designed benches and tables that do not match students' anthropometric dimensions often force them into awkward postures, such as leaning forward, hunching, or letting their feet dangle, which can result in musculoskeletal discomfort, back and neck pain, fatigue, and reduced concentration (Dianat et al., 2013a; Oyewole et al., 2010).Research consistently shows that a significant proportion of classroom furniture is mismatched to students' body dimensions, with mismatch rates often exceeding 50%, even in higher education institutions where students are assumed to have outgrown such issues (Parcells, Stommel, and Hubbard 1999).This mismatch not only contributes to the development of musculoskeletal disorders (MSDs) but also negatively affects students' academic performance, as discomfort and fatigue reduce their ability to focus during long lectures and study sessions (Dianat et al., 2013a; Parcells et al., 1999b). Ergonomic design principles aim to minimize these risks by ensuring that seat height, seat depth, and desk height correspond appropriately to students' anthropometric measurements, thereby supporting neutral posture, comfort, and concentration (Castellucci, Arezes, and Viviani 2010; Oyewole et al. 2010).Beyond addressing immediate physical comfort, ergonomically designed benches and tables also promote long-term health, since sustained exposure to non-ergonomic furniture during the university years can lead to chronic musculoskeletal problems later in life. Therefore, incorporating ergonomics into

classroom furniture design is not merely a matter of physical well-being but also a key determinant of academic efficiency, engagement, and the creation of healthier learning environments.

2. Objectives

- To design ergonomically fit classroom benches and tables that match the anthropometric dimensions of university students, promoting neutral posture and physical comfort.
- To minimize health risks such as musculoskeletal disorders and improve concentration, thereby improving students' academic performance.

2. Literature Review

Burnard and Kutnar studied human stress responses in working place with different wood types. They found that oak surfaces helped reduce overall stress levels, although walnut did not show the same measurable effect. The difference in stress recovery was not significant, probably because the experiment duration and sampling intervals were not enough to capture full recovery.(Burnard and Kutnar 2020).

The study was conducted by Veljovic to determine how the design and tilt angle of school desks affect the force on the spinal column of students of different body weights Using CATIA-based biomechanical and RULA assessments. The study emphasizes the importance of adaptable desk designs for ergonomically fit to reduce musculoskeletal disorders (Veljovic et al. 2020).

The design and testing of a wooden standing desk that was designed for school classrooms were carried out by Podrekar Loredan. In their approach, there is the incorporation of ergonomics, biophilic design, and anthropometric demands.The results show that wooden adjustable furniture reduces fatigues and improves learning environment (Podrekar Loredan, Prelovšek Niemelä, and Šarabon 2024).

Khoshabi developed an integrated MCDM approach to compare and rank different types of classroom furniture according to mismatch levels between the anthropometric dimensions of students and the measurements of furniture.Overall, this study concluded that the proposed MCDM framework can support decision-makers in choosing the best classroom furniture that provides good ergonomic compatibility with users' preferences. (Khoshabi et al., 2020)

Safin et al. examined how combining ergonomics and design education could be effective in preparing students for the challenges of interdisciplinary design work in real-life settings. According to the findings, students' understanding of ergonomics may be enriched through co-constructed, collective, and iterative pedagogical approaches,outlining a further need for stronger collaboration between ergonomists and designers in educational contexts (Safin, Pintus, and Elsen 2020).

3. Methodology

A cross-sectional ergonomic assessment was employed in this study to evaluate the compatibility between university students' anthropometric characteristics and the existing classroom furniture. The methodology consisted of three primary phases: anthropometric data collection, assessment of existing furniture dimensions, and a mismatch analysis using established ergonomic design equations. The procedure is shown in Figure 1.

3.1 Participant Selection

The study was conducted on the students of Rajshahi University of Engineering and Technology (RUET), Bangladesh. The total sample size considered were of 225 students comprising 165 male and 60 female undergraduate students.

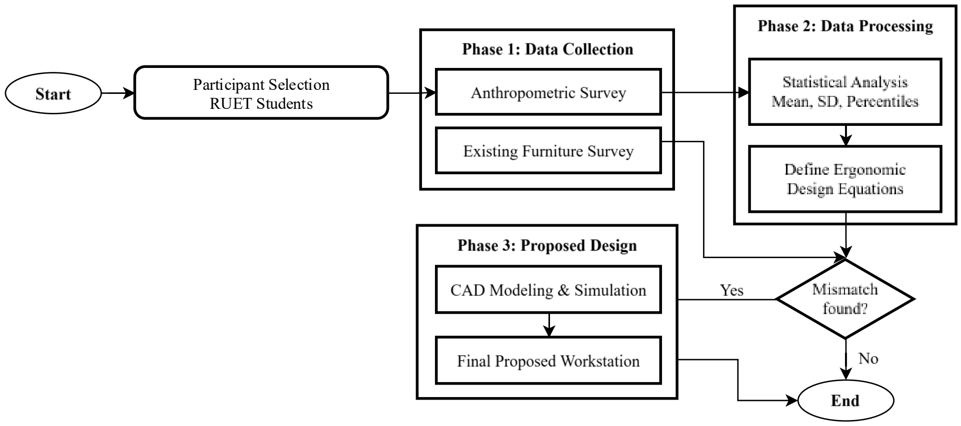

Figure 1. Procedural framework for the ergonomic assessment and design process.

To establish a reference database for ergonomic design**,** 11 anthropometric dimensions were measured from the participants. These dimensions were selected based on their direct relevance to seated workstation design. The measured variables included:

- Popliteal Height (PH) and Buttock-Popliteal Length (BPL) for seat height and depth determination.
- Sitting Elbow Height (SHE) and Sitting Shoulder Height (SSH) for desk and backrest height determination.
- Hip Breadth (HB) and Sitting Elbow Breadth (SEB) for seat width and desk depth requirements.
- Additional clearance dimensions such as Thigh Thickness (TT) and Buttock-Knee Length (BKL).

The data were analyzed statistically to determine the Mean, Standard Deviation (SD), 5th percentile, and 95th percentile values for each dimension. These percentiles were chosen to ensure the proposed design accommodates the widest feasible range of users, following the principle of "letting the small person reach and the large person fit".

3.2. Evaluation of Existing Furniture

A detailed survey of the existing classroom furniture was conducted to establish a baseline for comparison. The dimensions of the currently used benches and desks were measured using standard measuring tapes. Key parameters recorded included Seat Height (SH), Seat Width (SW), Seat Depth (SD), Desk Height (DH), and Seat-to-Desk Clearance (SDC). The existing design was found to be static (non-adjustable), with a seat height of 43.18 cm and a desk height of 78.74 cm.

3.3 Ergonomic Design Criteria and Mismatch Analysis

The core of the methodology involved a mismatch analysis, where the existing furniture dimensions were compared against the anthropometric limits of the student population. To define the "Acceptable Range" for each furniture dimension, specific design equations were applied. These equations link furniture dimensions to specific anthropometric percentiles (5th or 95th) to ensure compatibility. A dimension was classified as a "Mismatch" if the existing furniture value fell outside the calculated acceptable range derived from the student anthropometric data.

3.4 CAD Modeling and Prototype Design

Based on the calculated ergonomic ranges, a proposed design was conceptualized. SOLIDWORKS software was utilized to visualize the existing design flaws and to model the proposed workstation with corrected dimensions. The proposed design focused on optimizing critical dimensions; specifically adjusting Seat Height to 45–47 cm and Desk Height to 70–73 cm to correct the identified mismatches.

4. Principles of Ergonomic Design

The redesign of the classroom workstation followed a set of ergonomic principles grounded in the anthropometric characteristics of the student population. The corrected 5th and 95th percentile values were used as the primary reference for deriving acceptable ranges, ensuring that the workstation accommodates the vast majority of students while supporting stable posture and comfortable interaction with the desk. Each design parameter was reconsidered with respect to both biomechanical requirements and the specific functional tasks expected in an engineering classroom environment.

Correct Seat Height

Seat height plays a central role in establishing a stable and balanced sitting posture. A properly selected height enables the feet to rest flat on the floor and keeps the thighs level, reducing pressure beneath the legs. Based on the updated popliteal height percentiles, the ergonomic range for seat height extends from 38.0 cm to 49.6 cm. The proposed height falls within this range and maintains neutral lower-limb alignment, allowing students to sit without excessive knee flexion or elevation of the thighs.

Appropriate Seat Depth

Seat depth must support the length of the thighs while avoiding contact between the seat edge and the popliteal region. Using the revised buttock–popliteal length values, the recommended range lies between 33.8 cm and 45.8 cm. Increasing the seat depth in the redesigned workstation provides improved thigh support and helps distribute body weight more effectively, enhancing comfort during extended classroom sessions.

Adequate Back Support

A well-designed backrest supports the natural curvature of the spine and reduces strain on the lumbar and mid-thoracic regions. Updated anthropometric analysis suggests a desirable backrest height between 28.7 cm and 42.8 cm. The proposed backrest height falls within this interval and is intended to promote upright sitting and reduce fatigue by providing consistent contact across the lower back.

Aligned Desk Height

Desk height must be coordinated with seat height to maintain neutral shoulder and elbow posture when writing or performing coursework. Based on the corrected sitting elbow height and vertical clearance guidelines, the appropriate desk height for the student population ranges from 58.6 cm to 75.2 cm. The proposed height is positioned within this range so that students may work without lifting their shoulders or leaning forward excessively, thereby reducing muscular load in the upper limbs.

Sufficient Legroom

Adequate vertical and horizontal clearance beneath the desk ensures unrestricted leg movement and prevents compression of the thighs. The minimum seat-to-desk clearance derived from the updated thigh thickness measurements is 18.9 cm. The proposed workstation maintains clearance above this threshold, allowing students to shift posture comfortably and minimizing the risk of lower-limb strain during prolonged sitting.

Functional Seat and Desk Width

Although the acceptable ergonomic range for seat width extends from 41.0 cm to 48.4 cm per person, the existing width is intentionally preserved in the redesign because it accommodates engineering coursework that requires additional lateral space for drawing instruments, drafting sheets, and other materials. Similarly, the larger desk width supports shared working surfaces and enables students to manage larger reference documents without constraining movement. These dimensions exceed the standard ergonomic range but are retained to preserve functional workspace integral to the academic context.

Purposeful Desk Depth

The derived ergonomic range for desk depth is 38.7 cm to 40.9 cm, intended primarily for typical reading and writing activities. However, engineering students frequently use drawing boards, large-format sheets, and design tools requiring greater forward workspace. For this reason, the existing desk depth is maintained despite exceeding the upper ergonomic limit. Retaining the deeper surface supports discipline-specific tasks without compromising student comfort.

Design for a Diverse Population

The final design integrates the 5th to 95th percentile values from eleven anthropometric measurements, ensuring that both smaller and larger students can use the workstation comfortably. This percentile-based approach reduces mismatch risk by creating dimensions that accommodate variations in body size while supporting neutral posture across the population. The resulting bench–desk system is positioned to serve a diverse student group, reflecting both ergonomic requirements and the functional needs of an engineering classroom (Figure 2- Figure 3).

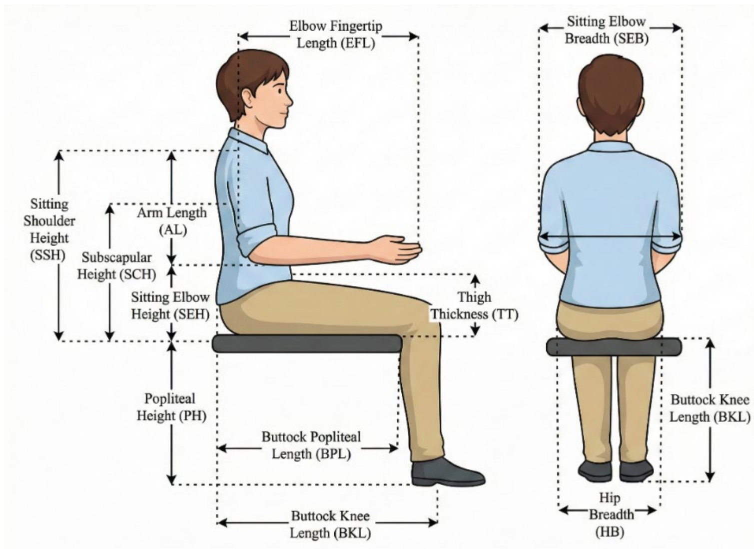

Figure 2. Anthropometry Of the participants, (a) right-side view (on the left), (b) backside view (on the right).

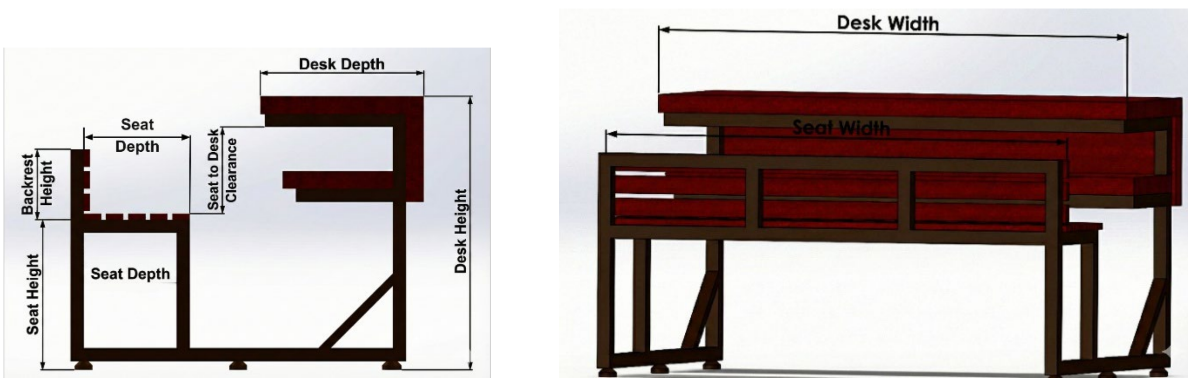

Figure 3. Bench Dimension

5. Study of Existing Design

The current bench–desk system is a fixed wooden structure designed for two students. Key dimensions-including seat height, seat depth, backrest height, desk height, and clearance-were measured and are listed in Table 1. Classroom observations showed frequent forward leaning, limited thigh support, and inadequate backrest contact. Shorter students struggled with foot placement, while taller students adopted slouched postures. These issues indicate clear mismatches between the workstation and student body dimensions, confirming the need for ergonomic redesign.

Table 1. Existing Workstation dimensions

Furniture Dimensions Name	**Size in cm**
Seat height (SH)	43.18
Seat width (SW)	140.97
Seat depth (SD)	30.48
Backrest Height (BH)	20.32
Desk height (DH)	78.74
Desk width (DW)	140.97
Desk depth (DD)	46.99
SDC (Seat to Desk Clearance)	24.89

In the existing design, the following problems were observed:

i) The seat depth was found inadequate for a grown person, more specifically an university student to seat comfortably. A major portion of leg rests in the air which puts load on the feet.

ii) The clearance between seat and desk was found inadequate to properly fit in a tall person. Discomfort and fatigue may arise due to prolonged seating in such condition

iii) The angle of the bench/ desk is parallel to the ground; this causes a slight discomfort while writing and Engineering Drawing (Figure 4).

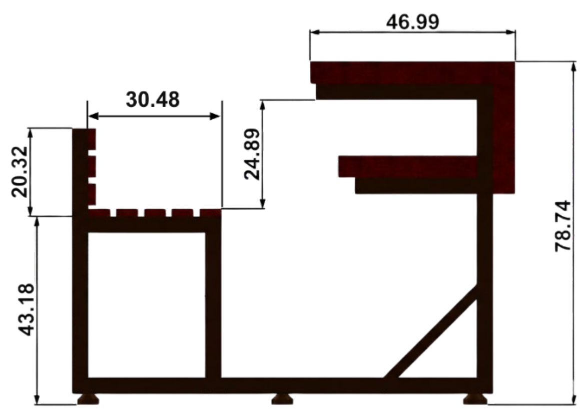

Figure 4. Existing Work Bench

5.Anthropometric Data Collection

Anthropometric measurements data were obtained using standard instruments, including an anthropometer and measuring scale, with all values recorded in centimeters. Eleven key variables relevant to seated workstation design were measured, including popliteal height, sitting elbow height, buttock–popliteal length, thigh thickness, shoulder height, elbow–fingertip length, and others.

For each variable, the mean and standard deviation were calculated, followed by estimation of the 5th and 95th percentiles using the formula *Mean ± 1.645 × SD*. These percentiles formed the basis for establishing ergonomic design criteria (Table 2).

Table 2. Anthropometric data of the lab experiment group

Dimensions	Min	MAX	Mean	SD	5th percentile	95th percentile
Popliteal height (PH)	372.8691	472.6621	436.8651	18.75963	406.0055	467.7247
Sitting elbow height (SHE)	187.5091	307.6746	233.4433	17.06086	205.3782	261.5084
Buttock-popliteal length (BPL)	394.2785	497.8091	452.1819	17.86849	422.7882	481.5755
Arm Length (AL)	325.3399	394.2811	358.0711	14.29189	334.561	381.5813
Thigh Height (Clearance) TT	125.5008	178.2571	153.1696	10.01478	136.6953	169.6439
Sitting shoulder height (SSH)	459.5081	555.7607	505.5581	17.50446	476.7633	534.3529
Subscapular Height (SCH)	469.3685	540.0654	507.3602	13.08929	485.8283	528.8921
Elbow-fingertip length (EFL)	385.4144	471.4993	439.0661	20.76797	404.9028	473.2294
Sitting Elbow Breadth (SEB)	390.0177	491.6269	441.2414	19.04595	409.9108	472.572
Hip breadth (HB)	328.2676	389.7907	354.8586	11.99078	335.2677	374.4502
Buttock-knee Length (BKL)	486.3461	548.1582	518.6682	11.53028	499.7009	537.6355

6. Derivation of Ergonomic Criteria

The ergonomic criteria for redesigning the workstation were derived by relating key furniture dimensions to the corresponding anthropometric measurements of the students. The 5th and 95th percentile values were used to ensure that the design accommodates the majority of users while preventing postural strain.

Seat height (SH) was determined from popliteal height (PH) by accounting for shoe allowance and lower-leg angle(Hoque et al., 2014; Saha et al., 2024), producing a recommended range(JFM et al., 2003; Parcells et al., 1999a) of *(PH + 30)cos30° to (PH + 30)cos5°*.

Seat width (SW) was linked to hip breadth (HB)(Evans et al., 1988), with allowable limits(Dianat et al., 2013b; Gouvali & Boudolos, 2006) defined between *1.10HB and 1.30HB*. Seat depth (SD) was derived from buttock-popliteal length (BPL)(Milanese & Grimmer, 2004), following the guideline(Afzan et al., 2012; Altaboli et al., 2015) that SD should fall between *0.80BPL and 0.95BPL* to support the thighs without compressing the popliteal region.
Desk-related dimensions(JFM et al., 2003; Milanese & Grimmer, 2004) were also determined from upper-body measurements(Bendix & Bloch, 1986). Seat-to-table height (STH) was based on sitting elbow height (SEH), with an acceptable range of *SEH to SEH + 50 mm*. Desk height (DH) was calculated by adding STH(García-Acosta & Lange-Morales, 2007; Woo et al., 2016) to the corrected seat height, resulting in a recommended range of *SHmin + STH to SHmax + STHmax*.

Additional ergonomic limits were established for backrest height (BH), seat-to-desk clearance (STC), backrest width (BW), table length (TL), table depth (TD), and the upper edge of the backrest (UEB), each derived through published anthropometric relationships. These equations were applied to the percentile data to generate the final acceptable ranges presented in the ergonomic criteria Table 3.

Table 3. Criteria Equation

Furniture Dimension	Anthropometric Basis	Design Equation	Range (mm)	Range (cm)
Seat height (SH)	PH5 & PH95	(PH+30)×cos30° to (PH+30)×cos5°	380 – 496	38.0 – 49.6
Seat width (SW)	HB95	(1.10×HB) to (1.30×HB)	409 – 484	41.0 – 48.4
Seat depth (SD)	BPL5 & BPL95	(0.80×BPL) to (0.95×BPL)	338 – 458	33.8 – 45.8
Seat-to-table height (STH)	SHE5	SEH to (SEH + 50)	206 – 256	20.6 – 25.6
Desk height (DH)	SH + STH	(SH_{min} + STH) to (SH_{max} + STH_{max})	586 – 752	58.6 – 75.2
Backrest height (BH)	SSH5 & SSH95	(0.60×SSH) to (0.80×SSH)	287 – 428	28.7 – 42.8
Seat-to-desk clearance (STC)	TT95	TT + 20	≥ 189	≥ 18.9
Backrest width (BW)	HB95	BW ≥ HB	≥ 372	≥ 37.2
Table length (TL)	BKL95	TL ≥ BKL	≥ 538	≥ 53.8
Table depth (TD)	SEB95, AL95, EFL5	(0.5×SEB + 0.342×AL + 20) to EFL	387 – 409	38.7 – 40.9
Upper edge of backrest (UEB)	SCH5	UEB ≤ SCH	≤ 487	≤ 48.7

This table lists the ergonomic criteria equations for each furniture dimension based on anthropometric data. It defines the acceptable range for seat height, depth, width, backrest, desk dimensions, and seat-to-desk clearance.

Table 4. Anthropometric Measurements and Match/Mismatch

Furniture Dimensions	Acceptable Range (cm)	Existing Furniture Dimension (cm)	Match	Mismatch
Seat height (SH)	38.0 – 49.6	43.18	Yes	No
Seat width (SW)	41.0 – 48.4	140.97	No	Yes
Seat depth (SD)	33.8 – 45.8	30.48	No	Yes
Backrest Height (BH)	28.7 – 42.8	20.32	No	Yes
Desk height (DH)	58.6 – 75.2	78.74	No	Yes
Desk width (DW)	≥ 37.2	140.97	Yes	No
Desk depth (DD)	38.7 – 40.9	46.99	No	Yes
Seat-to-Desk Clearance (SDC)	≥ 18.9	24.89	Yes	No

This Table 4 compares the existing furniture dimensions with the acceptable ergonomic ranges. It identifies which dimensions match or do not meet anthropometric standards.

7.Proposed Workstation Dimensions

The proposed dimensions were selected by applying the ergonomic criteria to the students' percentile data, ensuring proper posture and comfort for most users. Core elements such as seat height, seat depth, backrest height, and desk height were adjusted accordingly, while seat width and desk depth were retained to support engineering drawing activities (Table 5).

Table 5. Proposed dimensions

Furniture Dimension	**Acceptable Dimension (cm)**	**Existing Dimension (cm)**	**Proposed Dimension (cm)**	**Proposed Solution**
Seat height (SH)	38.0 – 49.6	43.18	43.18	Seat height falls within the acceptable ergonomic range. Retaining the current height supports stable foot placement and promotes a comfortable sitting posture.
Seat width (SW)	41.0 – 48.4 (per person)	70.48 per person (140.97 total)	70.48	Although the existing width exceeds the standard ergonomic range, it is intentionally maintained because engineering students require additional lateral workspace for drawing and drafting tasks. The current dimension supports these academic activities more effectively than narrower seating would.
Seat depth (SD)	33.8 – 45.8	30.48	35	Increase seat depth to support thighs properly and improve comfort.
Backrest height (BH)	28.7 – 42.8	20.32	32.56	Raise backrest to offer lumbar and mid-back support.
Desk height (DH)	58.6 – 75.2	78.74	75.74	Lowering the desk height ensures that the writing surface corresponds more closely with students' elbow height, encouraging neutral upper-limb posture and reducing shoulder fatigue.
Desk width (DW)	≥ 37.2	140.97	140.97	The current desk width already meets functional requirements and accommodates engineering coursework that involves drawing instruments and large notebooks. As such, no modification is necessary.
Desk depth (DD)	38.7 – 40.9	46.99	46.99	Depth is retained to provide sufficient workspace for engineering drawing tasks.
Seat-to-Desk Clearance (SDC)	≥ 18.9	24.89	24.89	Existing clearance allows free leg movement and remains adequate.

8. Proposed Workstation Design

The redesigned workstation integrates the proposed ergonomic dimensions into a revised bench–desk layout that supports neutral posture and improved usability. The CAD model illustrates the final configuration, reflecting all updated measurements and functional requirements for engineering students (Figure 5).

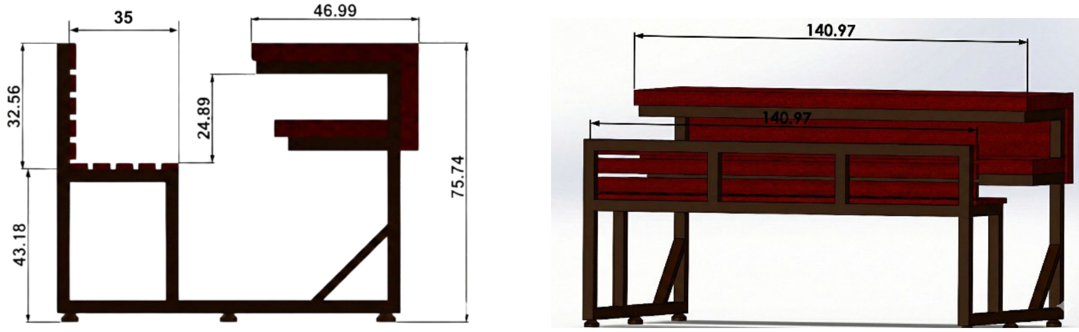

Figure 5. Proposed work bench

9. Discussion

The proposed workstation dimensions address the primary mismatches found in the existing classroom furniture. Improvements in seat height, seat depth, and backrest height aim to support neutral posture and reduce discomfort during prolonged sitting. The refined desk height aligns more closely with students' elbow level, helping to minimize forward leaning and shoulder strain. Although seat width and desk depth exceed the standard ergonomic ranges, these dimensions were retained to accommodate the larger workspace required for engineering drawing and design tasks. Overall, the redesign balances ergonomic fit with functional academic needs.

10. Conclusion

The study shows that integrating anthropometric data into workstation design leads to furniture that more accurately reflects the physical characteristics and learning activities of university students. The proposed dimensions enhance comfort, posture, and usability compared to the existing setup. As a natural extension of this work, future efforts may involve fabricating a prototype and evaluating its performance through structured user testing. Broader data collection across multiple departments and exploration of adjustable design features could further strengthen the workstation's long-term applicability and adaptability**.**

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