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Investigation On The Mismatch Of Classroom Furniture And Anthropometrics In Some Different Primary Schools (Public/Private) In Benghazi

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***Abstract*— The aim of this paper is to investigate the alignment between classroom furniture dimensions provided by school officials and the anthropometric data of primary school children in Benghazi, Libya. Physical measurements, including seat height, seat depth, seat width, backrest height of chairs, and desk height, were compared with student anthropometric data. A total of 398 students aged 7 to 12 participated in this study. Findings indicate a substantial mismatch ranging from 85.075% to 100% between children's anthropometric measurements and school furniture dimensions. Specifically, desk height was notably too high for students, especially in the first, second, and third grades. Consequently, the current matching proportions of school furniture in Benghazi with students' anthropometric measurements are deemed insufficient and in need of modification. Two alternative designs have been proposed: The first involves using the same size of separated chairs and desks for the first three grades and another design size for the last three levels. Meanwhile, the second design proposal is less efficient but perhaps the most feasible alternative to using only one modified size of the desk for all six grades' classrooms.**

***Keywords*— Mismatching; proportions Anthropometric; School; Furniture**

I. INTRODUCTION

Children spend about a quarter of their day at school, with much of that time devoted to sedentary activities such as reading, writing, and homework. Given the significant duration spent sitting, it is crucial for school furniture to accommodate children's needs and facilitate varied sitting positions. Prolonged sitting on inadequately designed chairs has been linked to musculoskeletal discomfort and pain, with low chairs correlating with neck and back pain, and high backrests contributing to lower back issues. Additionally, poorly designed furniture can impact student morale and hinder healthy development. Despite the importance of ergonomics in promoting productivity and reducing accidents in work environments, the school setting has not received adequate attention from ergonomists. Musculoskeletal problems among schoolchildren have prompted studies across various countries, which have examined the relationship between school furniture design and children's health and posture. These investigations aim to provide insights into appropriate furniture design tailored to children's anthropometry, offering valuable recommendations and guidelines for enhancing school environments. [1] The objective of their study was to determine whether design improvement is needed. the data were collected from 300 students their ages between 13-17 years old. In the study, stature dimensions for each child are taken while they are standing. All other dimensions measured while they are sitting erect on chair with

knees bent at 90. The results of this study explored that, the chair is either too high or too deep for the students. The analysis also shows that the desk is too high for most of the students. The variability between gender and age was found to have great impact on the mismatch levels. It was concluded that there is great concern which could result in students to have the risk of having back problems in the future. [2] evaluated the case in Hong Kong. A survey was conducted with 214 schoolchildren. They considered seat height, seat depth, desk clearance, and desk height as common measurements in furniture design based on ergonomic principles. For students' anthropometry, they used three main groups of measurement:

1. Body height,
2. Standing position: Shoulder to hip, hip breadth, hip to knee, knee to lateral ankle, lateral ankle to floor,
3. Sitting position: Shoulder to seat surface, shoulder to elbow, back to front of kneecap, back to popliteal, thigh thickness, Knee to floor, Popliteal to floor, and Hip breadth. The results of this study confirm that almost none of the subjects had a chair with appropriate dimensions.

The design of the classroom desks used in the basic education stage in public schools in the city of Benghazi was evaluated. The results of the evaluation revealed significant mismatches between the desk dimensions and students' anthropometry [3]. Examine the anthropometric measurements of preschool children and compare them with the dimensions of the preschool chairs in kindergartens in North Macedonia, Bulgaria and Croatia, in order to perceive the current situation and suggest improving for kindergarten furniture design. 848 children in 27 kindergartens participated in the research. A total of 36 types of chairs was found and measured [4] The literature describing the criteria and equations for defining the mismatch between students and school furniture was reviewed. A total of 2,261 volunteer subjects from 14 schools were included in the review. Fifteen studies met the criteria for this review, and 21 equations to assess 6 furniture dimensions were identified. Regarding seat height, there were significant differences between the two most frequently used equations. Although seat-to-desk clearance was evaluated based on knee height, this approach seems to be founded on the false assumption that students are sitting on a chair with appropriate seat height [5].

The integration of the Six Sigma methodology with ergonomic principles to eliminate CMSDs was studied. The study found that students are at high risk of developing CMSDs due to prolonged use of poorly designed furniture. The results regarding CMSDs are as follows: fatigue, joint and muscle pain (71%); shoulder and neck tension (70%); headache (63%); neck pain (53%); back pain (51%); leg joint pain (46%); shoulder and muscle pain (42%); elbow pain (42%); sleeplessness (insomnia) (40%); and hand pain (39%). The proposed solutions include two ergonomically designed student desks; consideration of students' requirements and anthropometric measurements; preparation of occupational health and safety workshops and/or seminars; administrative interventions; behavioral (personal) interventions; and other engineering interventions [6]. The methodology and guidelines for the design of ergonomic-oriented classroom furniture for first graders in the elementary school were proposed. This anthropometric analysis could be used to design ergonomic-oriented classroom furniture which would not only incorporate adjustability, but also improve the level of comfort for the intended users [7]. The anthropometric mismatch between the height systems of primary school furniture and children in Korea was analyzed. The results revealed that the height systems of the current desks matched the height of only half of the children [8].

To increase the degree of matching, new height systems for desks and chairs were developed using an algorithmic approach. Two furniture dimensions were suggested for both Year 1 and Year 6 based on the 5th and 95th percentiles. For Year 1, the seat depth and seat-to-desk height were increased to achieve an 84% and 80% match with students' anthropometry, respectively. For Year 6, a 100% match with students' anthropometry was achieved for the backrest height using the newly proposed dimension [9]. Additionally, [10] sought to improve the fit of school furniture sizes for European children. The data presented in the literature for European children mostly consist of mean and standard deviation per age. Anthropometric measures of school children aged 12-13 were determined. Twelve anthropometric data points were collected from 393 students (207 male and 186 female) using convenience sampling. Mismatches were identified when comparing these findings with the Standards of Classroom Furniture [11]. Another study aimed to determine whether the classroom furniture provided to high school students in Akure, Nigeria, is ergonomically fit. The objective was not only to analyze the ergonomic compatibility of the furniture but also to provide anthropometric data that could be used to design better-fitting furniture in the future. The evidence presented reveals a high level of mismatch between anthropometrics and furniture dimensions for users [12].

Furniture sizes from three different schools were compared with the anthropometric characteristics of Chilean students to evaluate potential mismatches [13]. This study analyzed the relationship between body dimensions from a sample of 195 Chilean students across three schools with varying economic levels but within the same grade. The results highlight the fact that classroom furniture is typically acquired and selected without prior ergonomic considerations.

Mismatches based on the rules adapted from [14] were determined by [1] as follows: for Popliteal height and seat height mismatch: A mismatch is defined when the seat height was either>95% or <88% of the popliteal heigh, for Buttock-popliteal length and seat depth mismatch: A mismatch is defined when the seat depth was either>95% or 80% of the popliteal height and for Knee rest height and desk height mismatch: A mismatch is defined as occurring when a desk was<2 cm higher than the knee height.

II. METHODOLOGY

A. Participants

A total of 398 students, including 165 males and 233 females, participated in this study from four schools (private/public) in Benghazi city. Each school has six grades, with students' ages ranging from 7 to 12 years. The sample was randomly selected during the 2021/2022 school year. Permission to use the necessary equipment for conducting the study was obtained from the administrators and principals of each school, and all students participated voluntarily. The equipment used in this study is an anthropometric

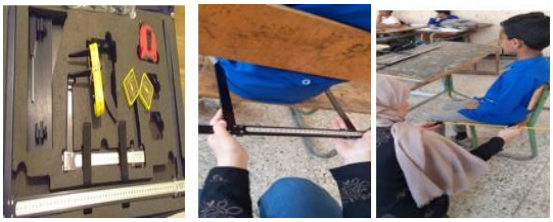

Fig. 1. Recording via an Anthropometric Calipers kit

calipers kit, as shown in figure 1.

B. Anthropometric Method

Anthropometric dimensions were measured based on previous studies [1], [2], [11], [14], [15], and [16], and these measurements were directly used to assess the current design of chairs and tables. During the measurements, each student was asked to assume two different positions: first, sitting upright with knees and elbows bent at ninety degrees, as illustrated in Figure 1; and second, standing upright without shoes. Additionally, weight measurements for each student were recorded using a balance.

C. Participants Anthropometric Measures

The anthropometric dimensions used in this study are stature, shoulder height (SH), buttock-popliteal length (BL), popliteal height (PH), hip width (HW), and elbow sitting height (ESH), as illustrated in Figure 2. On average, it took about 3-5 minutes to complete all measurements required for each student.

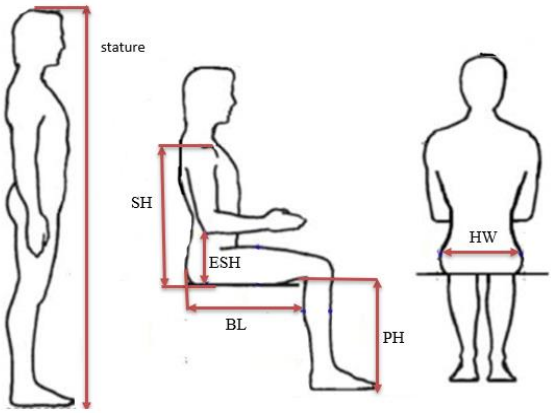

Fig. 2. *Measured Anthropometric Dimensions*

D. Measures Furniture

Public schools in Benghazi utilize uniform classroom seating and desks across all educational levels. The standardized dimensions used in this research include five important aspects: Seat Height, Seat Depth, Seat Width, Backrest Height, and Desk

Fig. 3. *Recording via an Anthropometric Calipers kit*

Height as shown in Figure 3.

III. DATA ANALYSIS AND RESULTS

A. School Desk (Chair/Table)

Five dimensions of classroom furniture(table/ chair) are shown in the Table I.

TABLE I. Dimensions of Furniture in Classrooms

Dimensions		Measurement
Seat Height	(cm)	45
Seat Depth	(cm)	40
Seat width	(cm)	52.5
Backrest height	(cm)	35
Desk height	(cm)	74

B. Antropometric Measurment

The data analysis was conducted using Excel 2019 and Minitab 20. Basic descriptive statistics, including percentages, means, standard deviations, maximum, and minimum values, were computed for anthropometric data. The results are recorded in table II Initially, we verified if there was any significant difference among anthropometric dimension measurements regarding students' gender (males and females). The results, as shown in Table III, indicate that the p-value ($p = 0.615$) is greater than 0.05. This leads to the conclusion that there isn't a significant difference between males and females of students in primary school in anthropometric measurements.

The study also used ANOVA to demonstrate that students' anthropometric dimensions, particularly stature, vary across academic grades up to the sixth year. The results, as illustrated in Table IV (P-value = 0.00), we conclude that there is a significant difference in students' anthropometric dimensions across classes.

TABLE I. Anthropometric Data for the Overal

Dimension	Grade	μ	σ	Min	Max
Height cm	1	124,86	6,02	116,5	**141**
	2	129,46	6,92	110	**143**
	3	136,33	5,53	113,2	**150,6**
	4	140,15	6,54	1155	**153,7**
	5	148,86	7,24	126,5	**169,3**
	6	152,76	7,4	133	**172**
Weight kg	1	26,372	4,007	19	**42,2**
	2	29,48	4,469	21,7	**41,2**
	3	36,17	7,93	23,9	**56,1**
	4	37,724	7,816	24,5	**63,9**
	5	45,194	6,877	24,9	**62,5**
	6	50,4	10,08	33,4	**83**
popliteal height (PH)	1	34,934	1,534	32,6	**39**
	2	36,097	1,748	31	**40**
	3	37,355	1,457	31,8	**41,4**
	4	38,456	1,704	34,7	**42**
	5	40,858	1,984	35,2	**46,6**
	6	41,893	1,91	37	**46,1**
Elbow sitting height (EH)	1	18,504	1,39	16,5	**22,5**
	2	19,133	1,455	16,6	**22,2**
	3	19,953	1,389	17,1	**22,2**
	4	20,256	1,603	15,2	**25**
	5	20,82	1,735	17,1	**27,2**
	6	20,703	1,566	16,7	**23,2**
knee height (K)	1	38,422	1,509	36,1	**42,5**
	2	39,595	1,764	34,2	**43**
	3	41,363	1,384	35,6	**45**
	4	42,31	1,61	38,2	**45,7**
	5	44,499	1,815	38,9	**49,6**
	6	45,475	1,853	40,5	**50,3**
Shoulder height (S)	1	41,346	2,258	38	**49**
	2	43,623	2,253	38	**50**
	3	45,838	2,2	40,8	**50**
	4	47,174	2,429	42	**52,5**
	5	50,11	2,956	41	**58,5**
	6	51,033	3,005	42,7	**58,8**
Buttock popliteal height	1	31,7	2,549	24,3	**39**
	2	35,533	3,065	27	**43**
	3	38,822	3,656	29	**48**
	4	39,263	2,72	34,5	**46**
	5	41,024	3,643	31,5	**49,1**
	6	41,788	2,766	29,5	**47**
hip width (HB)	1	28,703	2.549	24,3	**39**
	2	32,536	3.065	37	**43,1**
	3	35,825	3.656	29	**48**
	4	36,263	2.720	34,5	**46**
	5	38,027	3.643	31,5	**49,1**
	6	38,791	2.766	29,5	**47**

TABLE III. T- test for $(Height)_f$ vs $(Height)_m$

	N	Mean	StDev	SE Mean	P-Value
$(Height)_f$	233	135.8	6.4	0.81	0.615
$(Height)_f$	165	136.4	5.3	0.88	

TABLE IV. One-way ANOVA: Height (Stature) versus Grades

Factor Information

Factor	Levels	Values
Grade	6	1; 2; 3; 4; 5; 6

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Grade	5	39067	7813,48	176,20	0,000
Error	392	17383	44,34		
Total	397	56450.4			

C. Evaluation of the current chair and table

[16] and [17] used the equations that can be used to test the mismatch between anthropometric measures and furniture were evaluated, applying the methodology proposed , as shown in Table V.

TABLE V. Matching Criterion

Eq.	Dimensions	Matching Criterion
1	**Popliteal height (PH) & seat height** (SH)	(PH+2) cos30° <SH < (PH+2) cos5°
2	**Buttock-popliteal length (PB) & seat depth (SD)**	0.80 PB≤SD≤0. 95 PB.
3	**Hip width (HW) and seat width (SW)**	1.1 HW ≤SW≤ 1.30HW
4	**Elbow sitting height (ESH) and desk height (DH)**	EH+cos30°PH≤DH≤ cos5°PH+0.852EH+0.148SDH

When the desk dimension sets outside of these limits, then considered a mismatch; either above the upper limit or below the lower limit. Table VI gives the results of comparison of the desk dimensions to the related acceptable ranges.

D. Combination of Statistics and Optimization

The purpose of this technique is to design the table and chair via calculate the maximum percentage of matching between target population's body dimensions and the furniture set.

1) Chair design: It is essential to choose an appropriately designed chair to allow the student to sit comfortably, work efficiently, and provide appropriate support to the human body to reduce fatigue.

a) For seat height: The proportion of matching between seat height and body dimension (popliteal height) is determined via equation (5)

$$P\left(\frac{\left(\frac{SH}{0.996}\right)-\mu}{\sigma} \leq z \leq \frac{\left(\frac{SH}{0.866}\right)-\mu}{\sigma}\right) \quad (5)$$

That derived from equation (1) in Table V, where (μ = 34.934 and σ = 1.534) for students' popliteal height who are studying in the first year. To optimize this percentage, we calculated the matching proportion at various seat heights, which we recorded for 1st-grade students in Table VI. By adjusting the seat height within the range of 28 to 38 cm, we found the maximum match proportion to be 87.2% at a seat height of 32 cm. Therefore, the current seat height of 45 cm is not suitable for most students studying in the first year and should be changed to 32 cm for the 1st grade.

By the same manner, we can investigate all grades and find the optimal seat height for each grade from 2 to 6. The summary of calculations to find the optimal seat height for all grades is illustrated in Table VII.

TABLE VI. Proportion Matching of seat height for (1st Grade)

SH	SH/,866	SH/,996	P2	P1	P2-P1
28	32,333	28,112	0	0,045	0,045
29	33,487	29,116	0	0,173	0,173
30	34,642	30,12	0,001	0,425	0,424
31	35,797	31,124	0,007	0,713	0,707
32	**36,952**	**32,129**	**0,034**	**0,906**	**0,872**
33	38,106	33,133	0,12	0,981	0,861
34	39,261	34,137	0,302	0,998	0,696
35	40,416	35,141	0,554	1	0,446
36	41,57	36,145	0,785	1	0,215
37	42,725	37,149	0,926	1	0,074
38	43,88	38,153	0,982	1	0,018

TABLE VII. Maximum matching percentages of seat height for all grades

Grade	Optimal Seat height (cm)	Matching proportion
1	32	87.270 %
2	34	83.380 %
3	35	91.780 %
4	36	87,870 %
5	38	84,970 %
6	39	87,402 %

b) For Seat Depth (SD): We can calculate the proportion of matching students for the seat depth using the same procedures as explained above. The proportion of matching student body dimensions (Buttock Popliteal Length - PBL) with seat depth is calculated using equation (6)

$$P\left(\frac{\left(\frac{SD}{0.95}\right)-\mu}{\sigma} \leq z \leq \frac{\left(\frac{SD}{0.80}\right)-\mu}{\sigma}\right) \quad (6)$$

where μ= 31.7 cm & σ= 2.549 cm for Buttock popliteal who are studying in the first year. As a results, the maximum proportion of match 1st grade students is 71.11% when the seat depth is 28 cm. Additionall the optimal seat depths for the remaining grades have been computed and recorded in Table VIII. This table summarizes the largest matching proportions of seat depth for all grades.

TABLE VIII. Max. matching % of seat depth for all grades

Grade	Matching proportion	Optimal Seat depth (cm)
1	71.11%	28
2	68.11%	31
3	63.93%	34
4	78.21%	34
5	66.72%	36
6	79.75%	36

c) Seat Width (SW): [17] mentioned that the seat width should be large enough to allow space for side movements. Using Equation (3) from Table V, the proportions of matching for different seat widths are calculated via equation (7)

$$P(\%) = P\left(\frac{\left(\frac{SW}{1.3}\right)-\mu}{\sigma} \leq Z \leq \frac{\left(\frac{SW}{1.1}\right)-\mu}{\sigma}\right) \quad (7)$$

The maximum percentage of matching are summarised in the following Table IX.

TABLE IX. Matching Percentages of Seat width for all Grades

Grade	Matching proportion	Optimal Seat width (cm)
1	93.03%	34
2	62.54%	39
3	58.80%	43
4	72.81%	44
5	61.68%	46
6	75.40%	46

d) Backrest Height (B): From Equation 4 in Table V, the proportions of matching for different Backrest Heights (BH) are calculated by equation (8)

$$P\left(\frac{\left(\frac{BH}{0.8}\right)-\mu}{\sigma} \leq Z \leq \frac{\left(\frac{BH}{0.6}\right)-\mu}{\sigma}\right) \quad (8)$$

The summary of Matching proportion for all Grades as presented in next Table X.

TABLE X. Max. matching % of backrest height for all grades

Grade	Matching proportion	Optimal Backrest Height (cm)
1	98,16%	28
2	**99,43%**	30
3	99,56%	32
4	99,28%	33
5	98,17%	35
6	98,48%	35

***2) Table design*:** Since individuals vary in height, therefore we need to estimate the proportion of students matching the current table height. We can apply the same procedures used earlier to determine the proportion of students matching seat height. From Table I, the current desk height is 74 cm. Equation (5) mentioned in Table V provides the desk height limits Then, the proportion of students' body dimensions at different table heights is formulated by equation (9)

$$P\left(\frac{(DH-29.88)-21.885}{1.251} \leq Z \leq \frac{(DH-25.98)-18.504}{1.39}\right) \quad (9)$$

The matching proportion of students in 1st grade is listed in Table XI at different desk heights. As you see,

if the desk height is decreased from 65 cm to 44 cm, the maximum match proportion find with value of 99% at a desk height of 53 cm.

TABLE XI. Match % of students' anthropometric (1st)at different desk heights

DH	DH-(,996*PH)	DH-(,866*PH)	P1	P2	P1-P2
44	10.12	14.02	0	0	0
47	12.12	16.02	0	0,10	0,10
51	16.12	20.02	0	0,94	0,94
53	**18,12**	**22,02**	**0**	**0,99**	**0,99**
58	36.12	40.02	0,85	1	0,15
65	40.12	44.02	1	1	0

By using the same method, we can analyze all grades and determine the optimal desk height for each grade from 2 to 6. The maximum percentage of matching for all grades is summarized in Table XII.

TABLE XII. Maximum matching percentages of desk height for all geades

Grade	Matching proportion	Optimal Desk Height (cm)
1	99.3%	53
2	99.45%	55
3	99.61%	56
4	99.50%	58
5	99,305%	61
6	99.86%	62

E. Proposed Designs

Based on our analyses, we conclude that the size of the current desk is not compatible with the dimensions of the students' bodies in all classrooms, especially in the first three grades, where the percentage of match was very low and then increased slightly in the fourth, fifth, and sixth grades. To address this issue, several alternative designs can be considered. This study suggests the most practical alternatives for developing the desk dimensions of the current design. Two alternative designs have been proposed; The first involves using one size of separated chairs and desks for the first three grades and another size for the last three levels. The second proposal, although less efficient, may be the most feasible alternative, which involves using only one modified size of the desk for all six grades' classrooms. Note that in all proposed designs, the under-desk storage shelf was disregarded since it is mostly not utilized by students, as observed during the measurement process. Moreover, considering this shelf in our design would result in table clearance that does not match the students' knee height. Therefore, we will propose alternative storage solutions that students may utilize for storing their bags.

1) First Proposed design: The proposed design computed the two averages to suggest two new designs: one for the first three grades (1st, 2nd, 3rd) and another for the last three grades (4th, 5th, 6th) that offer the maximum possible matching percentages. These values are listed in Table XIII and Table XIV

From this design the matching proportions was increased and improved compared to the current design the largest percentage of matching is 84% at seat height 33.67 cm and 37.67cm for grade 3 and 5. This means these seat heights are more convenient for 3rd grade and 4th.

TABLE XIII. Two averages of desk dimensions for proposed

Average	Seat height	Seat depth	Seat width	Backrest height	Desk height
G1, G2 &G3	33,67	31	38,67	30	**54,67**
G4, G5 &G6	37,67	35,33	45,33	34,33	**60,33**

TABLE XIV. Matching percentages for first proposal design

Desk dimensions	Matching proportion%					
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	**Grade 6**
Seat height	41,19	56,27	8537	88,52	56,08	**43,16**
Seat depth	35,45	55,**44**	62,19	73,47	50	**44,5**
Seat width	40,91	56,62	57,24	68,68	58,04	**52,37**
Backrest height	69,41	93,57	97,07	96,03	98,44	**97,68**
Desk height	74,41	82,62	99,54	99,26	77,26	**64,88**

The study considered the average values of each desk dimension across all levels as a second proposed design, as detailed in Table XV.

TABLE XV. Averages of optimal desk dimensions for second propsed design

Seat height	Seat depth	Seat width	Backrest height	Desk height
35,66667	33,16667	42	32,16667	57,5

2) Second Proposed design*: Although, these desk dimensions values enhanced the average percentage of match for the six grades but, these matching percentages were lower than the matching percentage compared to the previous design as shown in Table XVI. Moreover, this design still consider is better than the existing one.*

TABLE XVI. *Matching percentages for 2nd proposal design*

Desk dimensions	Matching proportion%					
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Seat height	41,19	56,27	85,37	88,52	56,08	43,16
Seat depth	35,45	55,44	62,19	73,47	50	44,5
Seat width	40,91	56,62	57,24	68,68	58,04	52,37
Backrest height	69,41	93,57	97,07	96,03	98,44	97,68
Desk height	74,41	82,62	99,54	99,26	77,26	64,88

In view side of feasibility, this one-size-for-all design is possibly the most applied, as it is still more economical than a previous proposed design, requiring relatively some modifications to existing design measurements

IV. CONCLUSIONS

The following conclusions based upon the current study: There aren't any significant differences between body dimensions of female and male students. This result helped to specify in the design of furniture without considering student gender. The investigation of match between existing school furniture (seat and table) dimensions and students' body dimensions resulted insignificant frequency of mismatch particularly for seat height, table height. The size of the current desk design is bigger than the body sizes of the students in the six grades considered in this work. Therefore, the students' posture is not good because the angle between the upper and lower arm was greater than 90 degrees. This can increase the tension in muscles and cause a decrease in the ability of students learning and concentration during the lecture and can cause serious health problems. Compared with the matching percentages of the current design with the proposed designs, the proposed designs significantly improve these matching percentages.

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