Ergonomic Design of Classroom Furniture for High School Students of Bangladesh

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Abstract

Ensuring the facilitation students comfortable learning activities depends on couple of underlying factors and appropriate school furniture is one of the key factors. Idiosyncratically, the management of these schools could hardly pay attentions on this and have needful measure in practice due to couple of constrains like financial, technical capacities etc. As, students spend their 80% of school time on sitting position, it is very likely to ensure the supply of appropriate furniture for them, because long time sitting on inappropriate furniture jeopardizes developing back pain, neck pain, postural dysfunction and other musculoskeletal disorder etc. This bad habit acquired at the student stage may impact in the long run in the subsequent life stages. Therefore, this research identifies the notable mismatch between classroom furniture dimensions and anthropometric characteristics investigating on 300 Bangladeshi secondary school students (150 boys, 150 girls), aged 11-15 at where fifteen anthropometric measurements and eight dimensions from existing classroom furniture are measured by using standard measuring instrument and determines the mismatch between them.

In this research mismatching between body dimensions of the students and existing classroom furniture dimension of attributions with seat depth 97.99%, seat width 78%, seat height 75.52% and desk height 69.33% respectively is being observed closely and the higher level of mismatching is found. Based on the demand to accommodate appropriate classroom furniture for at least 80% students of secondary school of Bangladesh, this paper proposes a methodology and guideline for designing ergonomic oriented classroom furniture having dimensions for seat height (42cm-46cm), seat depth (36cm-38cm), seat width (30cm-35cm) and desk height (22cm-27cm). This study could be used to design suitable classroom furniture which would not only ensure adjustability but also enhance the level of comfort for the aimed users.

Keywords — *Ergonomic design, anthropometric measurements, Economic, Optimum*

I. INTRODUCTION

The purpose of the classroom furniture is to facilitate students learning activities. Thus, ergonomically designed classroom furniture makes study comfortable through eliminating physical impediments, more or less, in some extents, to leverage the students to concentrate on the day's lesson. On an average student spends a quarter of the day at school and 80% of the school time is mostly in the sitting position. So, ergonomically precise sitting posture is important factor for the elimination of musculoskeletal symptoms [1]. Poor posture of students using classroom furniture is considered as one of the major factors, which may increase the risk of developing musculoskeletal disorder [2]. Recent statistics have shown that students often usage the classroom furniture that is not appropriate with their anthropometric requirements [3-9]. The postural behaviour of school students is often influenced by the teaching method, design feature of classroom furniture and as the individual anthropometric dimensions [10, 11]. Therefore, anthropometric measures could be a good candidate to consider to designing classroom furniture.

In the most every developing country, especially Bangladesh, students often face with ergonomics-oriented problem in their classroom because of physically misfit status to match students' physical structure to the available classroom furniture. The big student size is also one of the straightforward problems found a lot in secondary schools [12,13]. In UK, researchers reported that school furniture design was seriously associated with upper back, neck and low back pains and physical disorder in school children aged 11-14 [14]. Therefore, the mismatching between student body dimensions and anthropometric measurements of the classroom furniture is inevitable problem.

Anatomo-functional matter is another consequence of this type of mismatching where musculoskeletal and postural dysfunctions can increase during high growth stage of the students [15]. Long sitting hours on improperly designed school furniture especially benches may cause health hazards in the younger generation and hampering their physical activities. In Bangladesh most of the high

school furniture is very poor in quality and the abrasive writing surface which is liable for the developing of ergonomic problems. Often, there is no consideration of anthropometric standard for designing classroom furniture because none in the throughout furniture manufacturing process is equipped in any academic or technical or engineering knowledge. In recent years ergonomic research has focused particularly on the designing of working furniture based on the biomechanics of human body. Some researchers dealt with the principles of the designing school furniture especially benches [16-21]. For designing school furniture in accordance with ergonomics, it should keep in mind that anthropometric measures widely vary across different age groups, genders and cultures. Student anthropometric dimensions vary within the same group, across different ages, in the same classes and in different cultures [22]. Several studies show that classroom furniture, especially bench, plays an important role in the maintenance of good sitting position [10]. Classroom furniture design serves a vital part for the students in the long term sitting posture. Since sitting habit is acquired at the children stage may be extremely difficult to change later life, therefore proper sitting posture is very important issue for the students. However, some prominent school authority of Bangladesh has shown a little interest to design of benches which are used by the students for prolonged period of school time. So, the aim of this research is to measure the anthropometric dimension of the students and existing classroom furniture, to identify the mismatching between body dimension and existing classroom furniture, to propose the better dimension of classroom furniture which is ergonomically fit.

II. METHODOLOGY

It is not practical to design classroom furniture that fit for all students irrespective to age group, gender, ethnics etc because body dimension of students are not versatile for all the students in the same class room. Moreover, students change their classroom in each academic session. But, optimise design such kinds of classroom furniture which fit for maximum students of all level can be possible applied and this will be convenient to use. This research is not only applicable for specific school but also applicable for all students of secondary school across Bangladesh as most of the students fall into the same ethnical status.

A. Sample

This study is carries out on a sample size of 300 students of 150 boys and 150 girls from secondary school is selected randomly. They have no physical disabilities. Schools include: Police Line School, Cantonment Public School and Churamonkathi High School. All the schools are located in Jessore city, Bangladesh. Students, of class VI to X and age range of 10-15 years normally, are taken. These three schools represent the three types of secondary school administration. For research purpose the data was collected through due authorisation channel of the school.

B. Measurement Techniques and Procedures

Normal healthy students of different anthropometric measurements are taken by an anthropometric scale in standard sitting and standing positions. A standard measuring instrument called Anthropometer is used to the purpose of measuring existing furniture dimensions. Mean values, maximum & minimum values, percentile and also standard deviation is calculated by using of statistical software named Microsoft Excel spreadsheet. The measurements are taken according to the method described by Weiner, Abeyskara and Pheasant [25]).

C. Anthropometric measurements

Anthropometric measurements are considered as the basis for ergonomically design furniture. Thus, designing the classroom furniture for this study the authors have considered the following anthropometric measurements (Fig. 1) [26].

Popliteal Height (PH): Distance taken vertically with 90^0 knee flexion, from the popliteal space, which is the posterior surface of the knee or popliteal space

Buttock-Popliteal Length (BPL): With 90^o knee flexion, distance was measured horizontally from the posterior surface of the knee to the posterior surface of the buttock [27].

Buttock-Knee Depth (BKD): Distance measured horizontally from the front of the kneecap to the back of uncompressed buttock.

Sitting Knee Height (SKH): Vertical distance from the top of the knee quadriceps muscles to footrest

Thigh Clearance (TC): Distance measured vertically from the stool surface to the highest point on the top of the right thigh.

Sitting Height (SH): Vertical distance from the tip of the head to the surface of the sitting object (stool)

Sitting Shoulder Height (ShH): Shoulder height refers to the vertical distance from the subject sitting surface to the top of the shoulder at acromion process. Shoulder is relaxed, with upper arm hanging freely.

Hip Breadth (HB): Maximum horizontal distance across the hips in the sitting position.

Sitting Lowest Rib Bone Height (SLRBH): It refers to the distance measured vertically from a horizontal sitting surface to the lowest rib bone.

Sitting Elbow Height (EH): Vertical distance from underside of the elbow

Elbow Fingertip Length (EFTL): It is refers to the horizontal distance from the back of the elbow to the tip of the middle finger at standard sitting position.

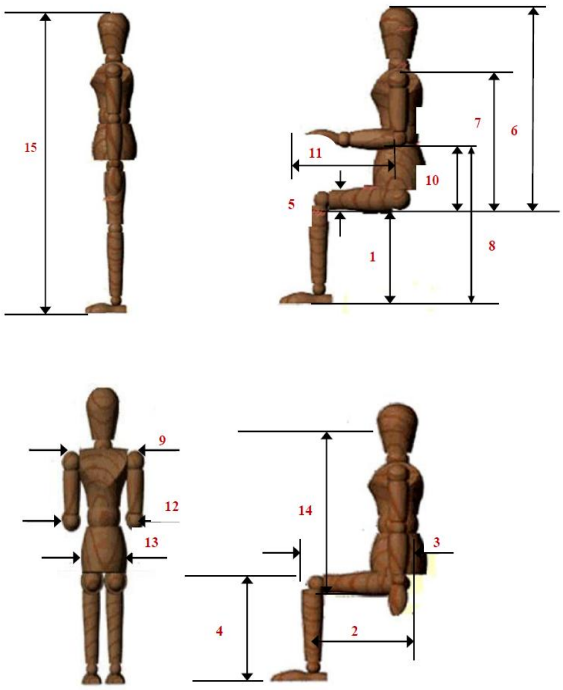
Elbow to Elbow Breadth (EB): Distance measured horizontally across the lateral surface of the elbows (standard writing position on the desk), spreading sideways was measured.

Hip Breadth (HB): It refers to the maximum horizontal distance across the hips at sitting position.

Eye Height (EH): Eye height refers to the vertical distance from inner canthus of the eye to the sitting surface.
Stature: It is the vertical distance from the footrest to the vertex.

D. Classroom Furniture and Body Dimensions Mismatch

Various ergonomic dimension of each individual student and classroom furniture are measured by using standard measurement instruments and anthropometer which helps us to find out the mismatching between them. Mismatching can be defined as incompatibility between the dimensions of the student's body and the dimension of the classroom furniture. Anthropometric and ergonomic principles be used to evaluate and identify the appropriate dimensions to design a standard classroom furniture which offer ergonomically fit for the maximum students. Various recommended relationships have been found in the literature to identify matching or mismatching (Table 1). The most commonly used are mentioned hereunder.



1. Popliteal height 2. Buttock popliteal length 3. Buttock knee depth 4. Sitting knee height 5. Thigh clearance 6. Sitting height 7. Sitting shoulder height 8. Sitting lowest rib bone height 9. Shoulder breadth 10. Sitting elbow height 11. Elbow fingertips length 12. Elbow to elbow breadth 13. Hip breadth sitting 14. Sitting eye height 15. Stature.

Fig. 1 Anthropometric Measurements

III. RESULT AND DISCUSSIONS

First of all the instrumentation takes place to find out the mismatching between students anthropometric measurements to furniture dimension of secondary school of Bangladesh and design school furniture (bench) as per ergonomic principles. The descriptive statistics of the 300 students (150 boys and 150 girls) of class VI-X including minimum, maximum, mean, standard deviation and percentile values of anthropometric measurements are taken which is shown in table 2. Table 3, shows the dimensions of existing classroom furniture. The mismatched percentage between the anthropometric measurements of school students by gender and grade level and the existing classroom furniture dimensions on the basis of seat height, seat depth, seat width, desk height, seat to desk clearance are recorded and shown in fig 2.

Table 1 : Classroom Furniture and Body Dimensions Mismatch

Recommended Relationships	Equation	Remarks
Popliteal Height (PH) against Seat Height (SH)	$(PH+3)\cos 30^0 \leq SH \leq (PH+3)\cos 5^0$	3 cm correction for shoe is concluded to the popliteal height in this research.
Buttock Popliteal Length (BPL) against Seat Depth	$0.80BPL \leq SD \leq .95BPL$	Based on the anthropometric data available in this study, a mismatch of seat depth to buttock popliteal length is defined as a seat that is either <80% or >95%of the buttock popliteal length
Hip Breadth (HB) against Seat width (SW)	$1.10HB \leq SW \leq 1.30HB$	SW should be at least 10% (to accommodate hip breadth) and at the most 30% (for the space economy) larger than hip breadth.
Sitting Elbow Height (SHE) against Desk Height (DH)	$SEH \leq DH \leq SHE+5$	Desk height would be 3-5cm higher than the sitting elbow height.
Thigh clearance (TC) against Seat to Desk Clearance (SDC)	$(TC+2)<SDC$	SDC should be 2cm higher than the knee height

The record shows that the mean height(stature) for boys is 161.13cm (SD 11.37) and for girls is 153.11cm (SD 7.08). We normally observe that girls are on average 8.02cm shorter than boys. The mean PH of the boys is 42.54cm (SD 2.74) and for girls is 42.92cm (SD 2.31). Similarly buttock-popliteal height is on average 4cm, buttock-knee depth is on average 2.89cm, sitting knee height is on average 2.83cm, thigh clearance is on average 0.33cm, sitting height is on average 4.71cm, sitting shoulder height is on average 1.61cm, sitting lowest rib bone height is on average 0.99cm, shoulder breadth is on average 2.03cm, elbow fingertip length is on average 3.13cm, elbow to elbow breadth is on average 1.31cm, hip breadth (sitting) is on average 1.36cm, sitting eye height is on average 4.59cm higher for boys than girls. But PH and sitting elbow height of the girls are is on average 0.38cm and 1.36cm higher than boys. Except PH and sitting elbow height, all anthropometric measured dimensions are higher for boys compare to girls.

This study is carried out to investigate the mismatching between the anthropometric measurement of Bangladeshi high school's students and the existing class room furniture. Therefore, the main goal of this study is to design the class room furniture for the students of Bangladesh according to ergonomic approach to lower or reduce discomfort, fatigue, pain, and musculoskeletal disorders. According to the Author the necessity of implementation of the ergonomic designing of the furniture for the students is extensive and pragmatic in the sense this will take little financial involving.

Anthropometric measurements of 6-10th classes students

Table2

	class	gender	PH	BPL	BKL	KH	TC	SH	ShH	HB	SEH	Stature
Min-Max	6	boy	39-49	35-50	42-57	42-57	7-15	64-89	39-63	14-27	24-40	133-173
		girl	38-48	35-45	37-50	42-52	7-14	64-83	41-54	18-27	22-36	141-162
	7	boy	38-52	35-48	37-58	40-61	9-19	64-87	39-72	14-28	19-38	138-180
		girl	38-47	35-48	42-57	44-55	7-15	65-87	42-57	19-26	20-38	136-163
	8	boy	40-56	35-51	38-62	42-59	10-19	66-90	42-68	14-26	26-39	140-184
		girl	38-46	35-49	39-59	43-54	9-15	64-87	43-64	17-29	21-36	139-166
	9	boy	41-53	36-47	40-58	48-59	10-16	68-89	40-58	17-27	27-37	144-179
		girl	38-49	34-47	41-59	45-56	9-16	64-87	46-59	17-27	23-35	148-167
	10	boy	42-52	37-51	42-59	45-60	11-16	68-92	47-62	16-27	24-37	145-179
		girl	37-47	37-49	41-58	44-56	10-16	64-87	39-58	19-32	28-40	134-172
Mean-SD	6	boy	42.1-2.4	40.8-3.7	49.4-4.4	49.9-4.1	11.3-1.6	73.5-7.4	48.4-6.2	19.8-2.6	27.9-3.7	152.3-12.6
		girl	40.7-7.9	40.4-2.8	45-3.1	47.8-2.6	11.5-1.3	71.8-4.1	48.4-3.3	21.8-2.3	25.6-2.3	149.3-5.6
	7	boy	43.8-2.5	40.9-3.1	48.1-4.5	49.9-4.3	12.2-2.3	74.1-6.8	50.5-7	20-3	27.6-3.8	158.5-10.2
		Girl	41.2-2.3	41.7-2.8	41.5-3.4	48.1-3	12.2-1.9	73-5	50.5-3.5	21-1.8	26.5-3.8	149.2-7.1
	8	boy	44.4-2.8	43.1-8.7	49.9-5.5	52.6-4.1	12.7-2.1	81.1-5.9	51.8-5.9	21.3-2.7	29.7-3.4	157.7-11.4
		girl	41.2-1.8	42.4-3.2	48.8-4	48.9-3.2	12.1-1.7	74.7-4.9	50.5-4.5	22.5-2.6	27.6-3.1	153-6.2
	9	boy	46.8-2.4	42-3.2	52.1-4.3	53.6-2.6	13.2-1.6	82.7-5.4	51.4-5.5	22.2-2.3	30.7-2.4	165.4-8.1
		girl	44.6-2.5	42.2-2.9	49.4-3.6	50.4-3	12.8-2	76.7-5.4	52-3.3	24-2.5	28.6-2.5	156.5-5.1
	10	boy	46.6-1.9	43.9-3.1	54.8-3.7	53-3	13.6-1.4	84.5-5.8	54.9-4.2	22.6-2.7	30.6-2.6	167.1-7.5
		girl	43.1-1.7	41.9-2.4	49.3-4.1	49.8-3.2	13.2-1.5	76.1-5.8	50.1-4.9	23.7-2.5	30.8-3.9	153.1-9
5%-50% tile	6	boy	40-43	35.9-40	42.9-50	44-50	9-11.5	65-73	39.4-48	17-20	24-27	134.9-151
		girl	38.4-42	36-40	38.4-46	43.4-48	10-12	66.3-71	42.4-50	18.4-21.5	22-25	141-149
	7	boy	41.4-45	35-41	42.9-50	43.9-52	9.45-12	65.4-77	42.3-52	15.4-20.5	21.9-28	142.8-160.5
		girl	38.4-43	37.4-42	43.4-49	44.4-49.5	10-13	68-75	46-50.5	19-22	22-26.5	143.3-154
	8	boy	41.4-46	37-42	42.3-52	45.4-53.5	11-12.5	69.8-82	43.4-54.5	16.9-22	26-29	143-164
		girl	39-42	37.3-42	42.8-49	43.4-49	9.4-12	67.4-74	44.3-50	18.9-22	22-27	145-152.5
	9	boy	43.4-47	36.4-41.5	44.9-53	49-54	10.4-13	71.8-83.5	40.4-52	18.4-22	28-30	150-167
		girl	39.4-45	38.4-42	45-49	45.4-51	10-13	69.4-76	47.4-51.5	18.9-24	25-29	148.4-156
	10	boy	43.4-47	38.3-44	47.1-54	48.4-53	12-14	74.2-84	48.4-56	18-23	26.3-31	153.9-168.5
		girl	40.3-43	38.4-42	42.9-49	45-50.5	11-13	65.4-76.5	41.4-51	22-23	28-29	136.4-154
95% tile	6	boy	48	47.75	56.1	57	13	86.1	59.8	23.6	35	171.1
		girl	44.6	45	49	51	13	80	52	26	29.5	158.2
	7	boy	49	45.5	55.5	57.1	16.6	85.5	63.2	25.1	35.6	172.1
		girl	46.1	46	54.5	54.5	15	82.1	56	24.1	36.5	162.5
	8	boy	48	48.2	60.1	58	18	89.5	61.2	26	36	179.7
		girl	45.5	48.5	55.6	54	15	81.5	58.1	27.1	32.2	162.7
	9	boy	51.5	47	57.5	58	16	89	58	26.1	35	178
		girl	48	45.5	56.2	54.5	16	85.6	58	27	33.1	165
	10	boy	48.5	48.1	59	56.5	16	91	61	26.5	34.6	177
		girl	45	45.55	56.55	55	15.5	84.5	57.5	18.5	40	167.5

So, it would be worth to take necessary steps to design school furniture ergonomically as early as possible. In this research, authors have designed single furniture for both boys and girls. If it would design separately for them then it would more effective and specific for its intended users. Besides, in the consideration of financial limitations only one furniture has been designed for the students of classes VI to X. If one could design furniture separately for all classes then it would be more standardized.

To determine the seat height the lowest distribution characteristics (5^{th} percentile) data are used by the author. The proposed dimension of the seat height for class 6-10 is 42, 43, 44, 45, and 46 which are appropriate for 83.30% school students. Desktop height for class 6-10 is select as 22, 24, 26, 27, and 27 cm which are appropriate for 86.65% students.

Table 3 : The Dimensions of Existing Classroom Furniture

Furniture dimension	Class	Existing dimension	Match	Total mismatch	Proposed dimension	Match	Total mismatch	Reduced mismatch
Seat height	6	50	8.33	91.67	43	75	25	66.67
	7	50	5	95	44	78.02	21.98	73.02
	8	50	3.32	96.68	44	81.34	18.66	78.02
	9	50	21.58	78.42	45	84.66	15.34	63.08
	10	50	18.26	81.74	45	87.98	12.02	69.72
Seat depth	6	30	14.94	85.06	36	81.34	18.66	66.4
	7	30	8.3	91.7	37	83	17	74.7
	8	30	8.3	91.7	38	79.68	20.32	71.38
	9	30	6.64	93.36	38	84.66	15.34	78.02
	10	30	4.98	95.02	38	86.32	13.68	81.34
Seat width	6	40	9.96	90.04	31	78.02	21.98	68.06
	7	40	3.32	96.68	32	74.7	25.3	71.38
	8	40	11.62	88.38	33	81.34	18.66	69.72
	9	40	26.56	73.44	34.5	78.02	21.98	51.46
	10	40	38.18	61.82	35.5	84.66	15.34	46.48
Seat to desk height	6	29	11.62	88.38	22	84.66	15.34	73.04
	7	29	13.28	86.72	23	79.68	20.32	66.4
	8	29	29.88	70.12	25	81.34	18.66	51.46
	9	29	44.82	55.18	26	78.02	21.98	33.2
	10	29	34.86	65.14	27	81.34	18.66	46.48
Seat to desk clearance	6	18	100	0	18	100	0	0
	7	18	96.28	3.72	18	96.28	3.72	0
	8	18	96.62	3.38	18	96.62	3.38	0

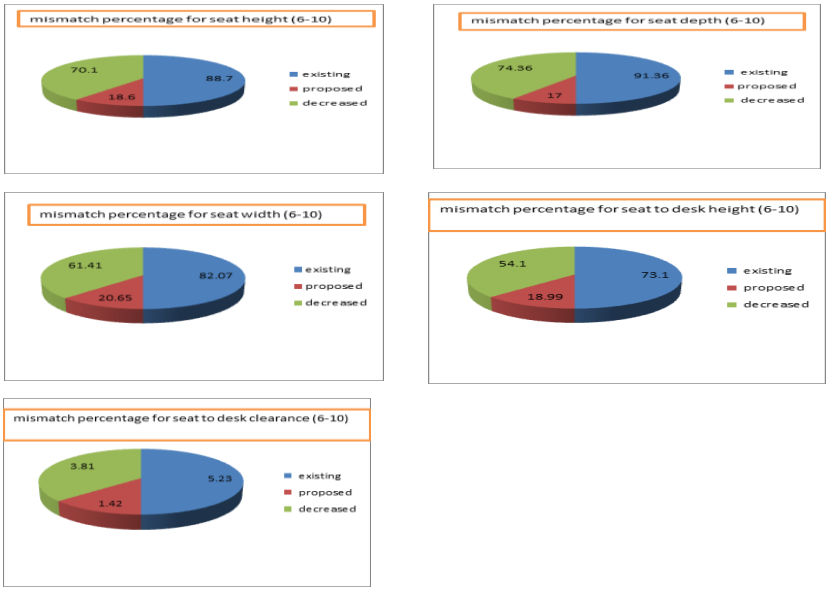


Fig 2 Mismatch Percentage

Fig 3 Wrong Furniture

Fig 3 shown Wrong furniture has been used by students. Wrong seat height dimension causes student feet unable to reach the ground and risk with thigh clearance. Long distance between low branches and high branches hamper elbow rest. Wrong furniture selection leads thigh clearance plus feet rest problem. High mismatch between seat height and desk height causes thigh clearance problem. New designed Classroom Furniture shown in fig 4.

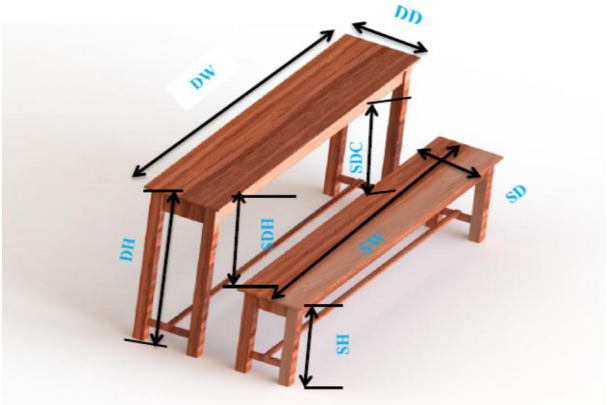


Fig 4. New Designed Classroom Furniture

IV. CONCLUTION

Form this study over 300 randomly collected sample sizes from 3 different institutes of class VI-X of different economic statuses in Bangladesh it is clear that mismatching level is notably high between existing schools furniture respective attributes and the student's anthropometric measurements. Hence, it is really challenging to propose versatile single design furniture for all students irrespective to age gender etc rather propose an optimum ergonomic designed furniture dimension so that a great number of students dimensions could be covered up truly as this is difficult to eliminate the mismatching between body dimension and schools furniture to the full. In this tune, Author notices high mismatching between body dimension (popliteal height , buttock popliteal length, sitting shoulder height, setting elbow height, hip breadth, and thigh clearance) of the school students and the class room furniture dimension (seat height , seat depth , seat width , desk height and seat to desk clearance). Moreover, for both boys and girls, the existing furniture dimension (especially seat height and desk height) are not in acceptable range, which may arise discomfort, fatigue, pain and musculoskeletal problem. Hence, optimum design is suggested considering both health concern and econo-financial background.

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