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Excel Interface Utilization in Automation of Design Process of Ergonomic Classroom Furniture for Primary School Pupils in Nigeria

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ABSTRACT - Usage of ergonomically unsuitable classroom chairs and desks promotes bad posture while bad postures affect students' learning, performance and health. Attention is rarely paid to ergonomic fitness of classroom chair and desk used by primary school pupils in Nigeria up till now. This study investigated classroom furniture status in the Staff School, University of Ibadan, Oyo State, Nigeria and developed an automated procedure for designing ergonomically suitable chair cum desk model for the pupils' use. A total of 72 Pupils were randomly selected from primary one to six. Relevant dimensions of pupils and their furniture were collected and used in establishing mismatch. The pupil anthropometry data were incorporated in the design process for the model of classroom chair cum desk in use and the design process automated to encourage production of ergonomically suitable classroom furniture for the pupils in the University of Ibadan Staff School. The Result shows that the classroom furniture items offered to the pupils in the school are ergonomically inadequate despite the assumed awareness of its implication.

Index Terms – Anthropometry, Ergonomic, Mismatch, Design, Furniture, Classroom, Automation

1.0 INTRODUCTION

Evidences abound that developing countries of the world were yet to be paying attention to offering ergonomically suitable chairs and desk to students for learning (Parcel et al, 1999; Haviarova *et al*, 2001; Joanne *et al*, 2007; Adewole and Olorunnisola, 2010; Ignacio *et al*, 2010). The use of non-functional and ergonomically unsuitable classroom furniture in Secondary School in Nigeria had been attested to by Adewole and Olorunnisola (2010). It appears Nigeria like many developing countries is yet to associate relevance to mitigating poor performance of school children through the use of ergonomic chairs and desks in their learning environment.

Recent report by the Nigerian Ministry of Education shows that school children performance has dropped greatly particularly in science related subjects. Effective learning in classroom, especially science subjects required student concentration while learning. However, the use of ergonomically unsuitable furniture for learning will demand frequent adjustment of user's posture at short interval of time. The frequent adjustment of learner's posture while under learning will almost certainly affect the concentration to learning process. The consequence may be greater for primary pupils who are expected to be at the foundation stage of learning. It is for this reason that a study like this will help to drum more support for the use of ergonomic furniture in Nigerian classroom.

Adewole and Olorunnisola (2010) noted that current method of classroom furniture production in Nigeria could be described as *one size fit all*. Although adjustable school chairs and desks would be efficient from an ergonomic viewpoint, in many African countries and particularly Nigeria, cost and material of construction are the limiting factors to adopting the use of adjustable approach in such furniture design. Another option would have been to have several sets of chairs cum desks from sizes from which school children are to choose the appropriate. The bane of this is the rigor of having to go through repeated design stages to evolve design templates for the several sizes that are expected to accommodate varying students' anthropometry. However, the constraint of the latter option can be circumvented by automating the design process using collected data of the targeted students' population.

There are inherent advantages in automating the design processes viz enabling elimination of human error associated with manually repeated design processes, avoid material and time wastage. Also the body dimension of newly admitted set of students can be easily accommodated by program modification. Since wood is still largely used for the construction of classroom chairs and desks in Nigeria (Adewole and Olorunnisola (2010), creating opportunity for students to choose the appropriate

furniture remain the viable option of solving ergonomic problem of classroom furniture. Hence, the effort by this study to develop an automated design tool for eliminating rigors involved in manual design will represent a significant contribution to mitigating ergonomic problem of classroom furniture in primary school in Nigeria

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2.0 MATERIALS AND METHODS

The study was conducted in three phases: data collection and determination of mismatch; design of chair cum desk model manually using results of structural analysis and averages of anthropometric data mainly for structural rigidity, and; design process automation to enable flexibility of using varying anthropometry data to adjust sections of the chair cum desk for ergonomic reason. The study was conducted in the University of Ibadan Staff School and 72 pupils whose ages ranges from 5–12 years were randomly selected from primary one to six. A total of 12 pupils comprising of equal number of male and female pupils were selected from each class. Information on the existing classroom furniture items currently offered to pupils in the schools was documented. Selected pupils anthropometry relating to the chair and desk dimensions (Chaffin and Anderson, 1991; Parcells *et al*., 1999; Ignacio *et al*, 2010) was collected alongside with the detail dimensions of the furniture used by the pupils for use in mismatch determination and furniture re-design. Mismatch in the pupils' body anthropometry and furniture dimensions were established using rules recommended by Chaffin and Anderson (1991) and Parcells *et al*. (1999). The maximum load, forces and bending moment expected on the chair and desk sections were evaluated by modifying the procedures used by Adewole (2010) for similar classroom chairs and desks used by Secondary School Students also in Ibadan. The results of the structural parameters were combined with averages of the pupils' anthropometry to evolve a design template that were automated using IF Statement on Microsoft Excel. The variable parameters for the IF Statement are Hip-Width (HW), Popliteal-Height (PH), Buttocks-Popliteal-Length (BPL) and Shoulder-Height (SH). The IF Statements used for the Seat-Height (SH), Seat-Width (SW), Seat-Depth (SD), Desk-Height (DH) and Desk clearance are as follow:

Seat Height

=IF(B5=K2,30.3,IF(B5=K3,33.3,IF(B5=K4,36.1,IF(B5=K5,39,IF(B5=K6,41.8,IF(B5=K7,44.7,IF(B5=K8,47.5,IF(B5=K9,50.4)))))))) Where: B5 is the PH range chosen while K2 – K9 are the PH ranges available.

Seat Width

=IF(B3=H2,17,IF(B3=H3,20,IF(B3=H4,23,IF(B3=H5,26,IF(B3=H6,29,IF(B3=H7,32,IF(B3=H8,35,IF(B3=H9,38)))))))) Where: B3 is the HW range chosen while H2 – H9 are the HW ranges available.

Seat Depth

=IF(B6=J2,29.5,IF(B6=J3,32.3,IF(B6=J4,35.2,IF(B6=J5,38,IF(B6=J6,40.9,IF(B6=J7,43.7,IF(B6=J8,46.55)))))) Where: B6 is the BPL range chosen while J2 – J8 are the BPL ranges available.

Desk Height =B9+13+2+7

Desk Clearance =B9+13+2 Where: B9 is SH

3.0 RESULTS AND DISCUSSION

3.1 Characteristics of Chairs and Desks in the University of Ibadan Staff School

The University of Ibadan Staff School pupils are using wooden chairs and desks exclusively. This further confirmed the finding by Adewole and Olorunnisola (2010) that wooden furniture remains the dominant form of classroom chairs and desks used in Schools in Ibadan, Oyo State, Nigeria. The reason for the preference for wood in the construction of classroom furniture had been observed by Khanam *et al* (2006) to be due to students' disposition to using wooden chairs and desk over other forms of chairs and desks. In accordance with the categorization by Adewole and Olorunnisola (2010), the chair and desk design in use at this school are Single-user (SU) chair combined with Multiple-user (MU) desk (Plate 1). Although the ergonomic suitability of this classroom chair cum desk model is given more priority by this study, preliminary investigation of their functional performance indicated that these furniture items were prone to high rate of failure. The high rate of failure of chairs and desks may be traceable to jettisoning of engineering principle in their design, poor workmanship during construction, wrong usage and adoption of one-size-fit-all approach in their manufacturing processes (Haviarova *et al*, 2001; Adewole and Olorunnisola, 2010).

Plate 1. SU chair and MU Desk in staff school

3.2 Pupils' Anthropometry and Their Chair Dimensions

Table1 presents the summary of the anthropometry of the pupils involved in the study. The summaries for the male pupils were presented first followed by female pupils result before summarizing for both male and female pupils. The female pupils appeared to be heavier than their male counterparts, with average body weight of 26.9Kg and 26Kg respectively. The average hip width of male pupils was 26.46cm compared to 27.76cm for the female pupils, while the average buttocks- popliteal length for male and female pupils was 37.08cm and 38.25cm respectively. These findings agree with research by Parcells *et al* (1999), Lin and Kang (2005), indicating slight variations in the anthropometries of male and female, establishing the fact that sex is one of many parameters that influence human anthropometry. The variation was however insignificant as sex alone would not necessarily dictates the need for different chair and desk combinations in primary schools. Tables 2 summarized the measurement of wooden chairs and desk used by the pupils whose anthropometric were collected.

Table 1: Summaries of the Anthropometry of the 72 Pupils Used for the Study

BOYS N = 36									
	Age (yrs)	BW(Kg)	SB(cm)	HW(cm)	SH(cm)	EHS(cm)	TT (cm)	BPL(cm)	PH (cm)
Average	8.36	26.00	34.88	26.46	39.31	13.36	12.33	37.08	45.52
Maximum	12.00	35.00	39.00	32.00	48.5	17.50	14.50	47.00	52.00
Minimum	5.00	17.00	30.5	24.00	14.00	9.50	10.00	32.00	39.50
SD	1.73	5.24	2.23	1.72	6.54	2.21	1.18	3.90	3.56
GIRLS N = 36									
	Age (yrs)	BW(Kg)	SB(cm)	HW(cm)	SH(cm)	EHS(cm)	TT (cm)	BPL(cm)	PH (cm)
Average	8.31	26.90	34.71	27.76	40.58	13.34	12.96	38.25	45.01
Maximum	11.00	55.30	41.50	34.00	53.00	19.00	19.00	50.00	54.00
Minimum	5.00	14.00	28.50	13.50	34.00	9.40	10.00	31.00	32.00
SD	1.80	9.30	3.20	3.50	4.80	2.60	2.30	4.10	4.80
POOLED ANTHROPOMETRY FOR MALE AND FEMALE N = 72									
	Age (yrs)	BW(Kg)	SB(cm)	HW(cm)	ShH(cm)	EHS(cm)	TT (cm)	BPL(cm)	PH (cm)
Average	8.30	26.50	34.80	28.10	40.00	13.40	12.70	37.70	45.30
Maximum	12.00	55.30	41.50	34.00	53.00	19.00	19.00	50.00	54.00
Minimum	5,00	14.00	28.50	13.50	14.00	9.50	10.00	31.00	32.00

Table 2: Summaries of Dimensions of Chairs and Desks Used By the Pupils

S/N	Dimension (cm)	Average	Maximum	Minimum
CHAIR FEATURES				
1	Seat Height	42.30	47.00	36.50
2	Seat Depth	39.20	41.00	37.00
3	Seat Width	32.70	34.00	31.00
4	Backrest Height	41.20	49.00	35.00
5	Chair leg Depth	4.47	5.84	4.00
6	Chair leg Breadth	3.73	4.00	3.00
7	Chair Side Rail Depth	5.97	6.00	5.80
8	Chair Side Rail Breadth	2.20	2.20	2.20
DESK FEATURES				
1	Desk Height	67.80	76.00	56.00
2	Desk Clearance	55.70	63.00	45.00
3	Desk Leg Depth	5.97	6.00	5.80
4	Desk Leg Breadth	3.00	3.00	3.00
JOINT: TENON FEATURES				
1	Depth	1.67	2.00	1.60
2	Breadth	0.80	0.80	0.80

3.3 Comparison of students' Anthropometry and classroom furniture dimensions

To establish possible mismatch between the students' anthropometry and their furniture, the following rules from a related study by (Parcells *et al*., 1999; Chaffin and Anderson, 1991) was adopted.

1. ***Mismatch in popliteal and seat height*****:** a mismatch is established when the seat height is greater than 95% of the popliteal height or less than 88% of the popliteal height.
2. ***Mismatch in Buttock- popliteal length and seat depth mismatch****:* a mismatch is established when the seat depth is greater than 95% or less than 80% of the popliteal length.
3. ***Kneel Height and Desk Clearance mismatch***: a mismatch is established when the desk-kneel clearance is less than 2cm. There must be minimum of 2cm difference between the kneel height and the distance from the base of the desk.

The seat height for the single user wooden chair surveyed for the pupils was 42.3cm while the corresponding 95th and 88th percentiles of the male popliteal height was 50.63cm and 49.4cm respectively, and 53.13cm and 50.9cm for the females respectively. Applying the rule in (1) above, it follows that the seat height is not fit for both males and female students. The seat depth of the existing chairs was discovered to be 39.2cm while the corresponding 95th and 80th percentiles of the male buttocks popliteal length was 44.13cm and 40cm respectively, and 44.13cm and 41cm for the females respectively. Adopting the rule in (2) above affirm that the seat depth of the existing chair is not fit for both gender in the school. These may be confirmed from the table below.

Table 3. Mismatch Information on the SU chair Surveyed

Sex	Chair Dimension	Mean(cm)	Anthropometry variable	95%	88%	80%	REMARK
Male	Seat height	42.3	Popliteal Height	50.63	49.4	49	**Not Fit**
	Seat depth	39.2	Buttock Popliteal Length	44.13	41	40	**Not Fit**
Female	Seat height	42.3	Popliteal Height	53.13	50.9	48.5	**Not Fit**
	Seat depth	39.2	Buttock Popliteal Length	44.13	43	41	**Not Fit**

There is therefore a need to re-design the seat depth and seat height of the SU chair to fit the users.

3.4 Design of SU chair and MU Desk.

Here, maximum load, forces and bending moment expected on SU chair and MU desk as well as their legs was evaluated and used to re- design the chair seat chair legs, seat rail and joint as well as the joint, legs and rail of the MU desk to correct the earlier established mismatch and also to improve the furniture performance, details of which can be found in the appendix. Using the maximum parameters to design the chair:

Weight = 55.3Kg (553N); HW = 34cm (340mm); PH = 54cm (540mm); SH = 53cm (530mm); BPH = 50cm (500mm). The summary of the design result of the SU chair, MU desk and the joints is given below.

Table 4 Summary of the forces and stresses acting on the Chair

FORCES DESCRIPTION	MAGNITUDE	EQUIVALENT STRESSES
F_v Axial Force	393.7N	0.1997N/mm^2
F_h Shearing Force	0N	0N/mm2
G_v Axial Force	0N	0N/mm2
G_h Shearing Force	553N	0.4206 N/mm^2
$F_{b\ (CD)\ at\ point\ c}$ Bending moment	238,343Nmm	50.94N/mm^2
$F_{b\ (CE)\ at\ point\ c}$ Bending moment	238,896Nmm	51.1N/mm^2
$F_{b\ (CB)\ at\ point\ c}$ Bending moment	-276,500Nmm	-22.4N/mm^2

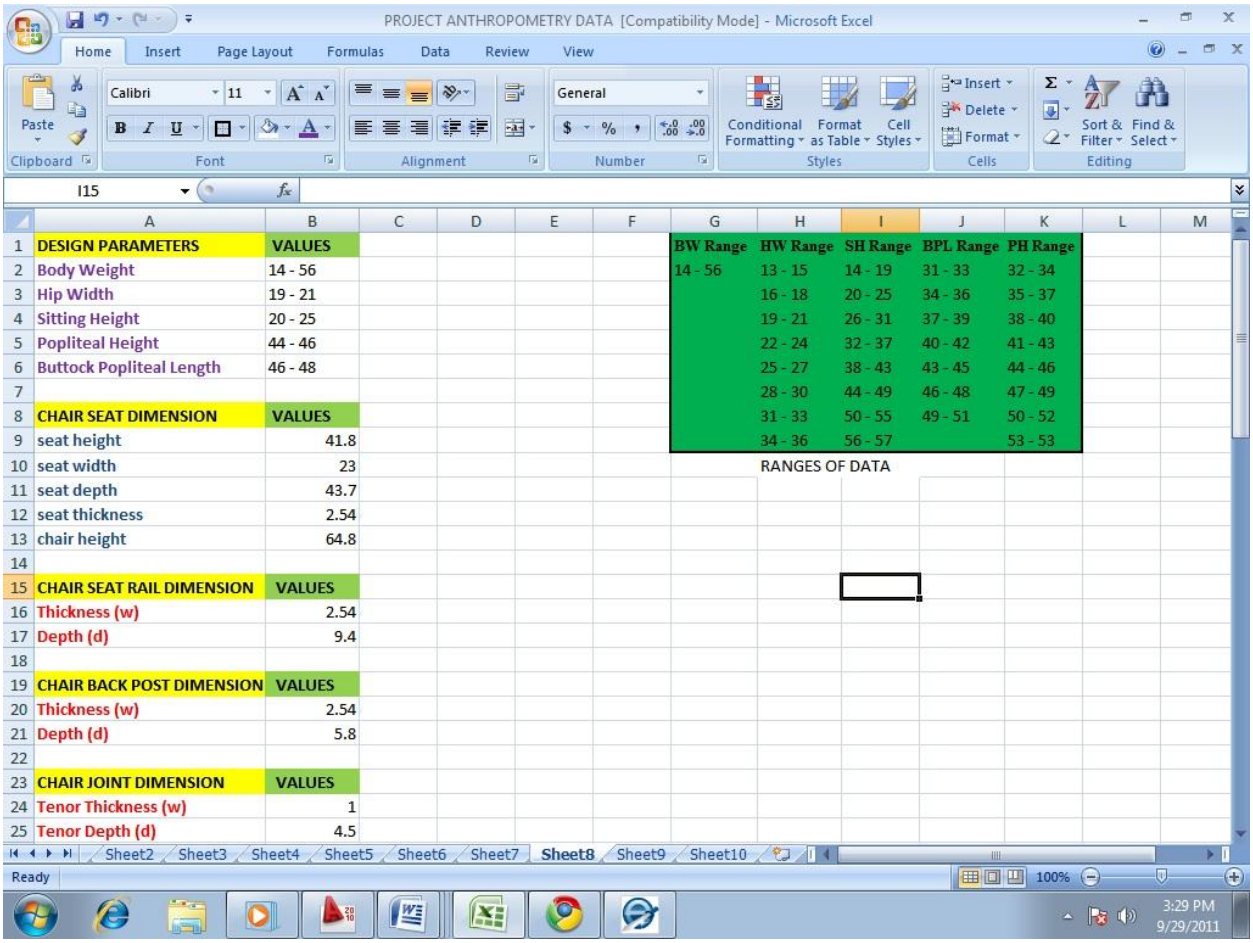
Table 5: Comparison of Critical Dimensions of Existing /Re-Designed Chair and Desk

S/N	Existing Dimensions		Re – Designed Dimensions	
	Chair Sections			
1	Seat rail thickness	= 22mm	Seat rail thickness	= 25.4mm
2	Seat rail depth	= 60mm	Seat rail depth	= 94mm
3	Back Post thickness	= 22mm	Back Post thickness	= 25.4mm
4	Back Post depth	= 58mm	Back Post depth	= 58mm
5	Seat thickness	= 15mm	Seat thickness	= 25mm
	Chair Tenon Sections			
6	Thickness	= 8mm	Thickness	= 10mm
7	Depth	= 20mm	Depth	= 44.9mm
8	Length	= 5mm	Length	= 15mm
	Desk and Its Tenon Sections			
	Desk leg thickness	= 30mm	Desk leg thickness	= 34mm
	Desk leg depth	= 60mm	Desk leg depth	= 94.5mm
	Tenon depth	= 20mm	Tenon depth	= 76.2mm
	Tenon width	= 8mm	Tenon width	= 17.4mm

3.5 Design Automation

The design process of an ergonomic chair and desk is rigorous and thus, the need to automate the design process to eliminate errors and design rigors involved in providing more than one design/size for students' use is inevitable. Microsoft Excel interface was designed for this purpose, using insert function tool, IF statement tool and data validation tool. The interface include a drop down menu for inserting independent design parameters i.e. body weight, hip width, sitting height, popliteal length and buttock – popliteal length which in turn generate a design output values i.e. seat height, seat width, seat depth, seat thickness, chair height, chair and desk structural components thickness and width as well as the desk height, desk leg clearance and tenor joints thickness and width. Fig 1.0 shows the appearance of the Microsoft Excel interface.

Fig 1.0 The Microsoft Excel interface



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	DESIGN PARAMETERS	VALUES					BW Range	HW Range	SH Range	BPL Range	PH Range		
2	Body Weight	14 - 56					14 - 56	13 - 15	14 - 19	31 - 33	32 - 34		
3	Hip Width	19 - 21						16 - 18	20 - 25	34 - 36	35 - 37		
4	Sitting Height	20 - 25						19 - 21	26 - 31	37 - 39	38 - 40		
5	Popliteal Height	44 - 46						22 - 24	32 - 37	40 - 42	41 - 43		
6	Buttock Popliteal Length	46 - 48						25 - 27	38 - 43	43 - 45	44 - 46		
7								28 - 30	44 - 49	46 - 48	47 - 49		
8	CHAIR SEAT DIMENSION	VALUES						31 - 33	50 - 55	49 - 51	50 - 52		
9	seat height	41.8						34 - 36	56 - 57		53 - 53		
10	seat width	23						RANGES OF DATA					
11	seat depth	43.7											
12	seat thickness	2.54											
13	chair height	64.8											
14													
15	CHAIR SEAT RAIL DIMENSION	VALUES											
16	Thickness (w)	2.54											
17	Depth (d)	9.4											
18													
19	CHAIR BACK POST DIMENSION	VALUES											
20	Thickness (w)	2.54											
21	Depth (d)	5.8											
22													
23	CHAIR JOINT DIMENSION	VALUES											
24	Tenor Thickness (w)	1											
25	Tenor Depth (d)	4.5											

3.6 Furniture Design Chart

Table 6 below shows the SU chair and MU Desk design chart as produce with the Microsoft excel interface for the use of the school furniture manufacturer. Different 8 design and sizes are generated which can be use to accommodate different sizes of primary school pupils.

Table 6. SU chair and MU Desk design chart

DESIGN INPUTS (ANTHROPOMETRY)					DESIGN OUTPUTS (FURNITURE DIMENSION)					
BW Range	**HW Range**	**SH Range**	**BPL Range**	**PH Range**	**SH**	**SW**	**SD**	**CH**	**DH**	**DC**
14 - 56	13 - 15	14 – 19	31 – 33	32 - 34	30.3	17	29.5	47.3	52.3	45
	16 - 18	20 – 25	34 – 36	35 - 37	33.3	20	32.3	56.3	55.3	48.3
	19 - 21	26 – 31	37 – 39	38 - 40	36.1	23	35.2	65.1	58.1	51.1
	22 - 24	32 – 37	40 – 42	41 - 43	39	26	38	74	61	54
	25 - 27	38 – 43	43 – 45	44 - 46	41.8	29	40.9	82.8	63.8	56.8
	28 - 30	44 – 49	46 – 48	47 - 49	44.7	32	43.7	91.7	66.7	59.7
	31 - 33	50 – 55	49 – 51	50 - 52	47.5	35	46.6	100.5	69.5	62.5
	34 - 36	56 – 57		53 - 53	50.4	38	46.6	106.4	72.4	65.4

Legend: **HW Range** = Hip Width Range (cm), **SH** = Seat Height (cm), **SH Range** = Sitting Height Range (cm), **SW** = Seat Width (cm), **BPL Range** = Buttock-Popliteal Length (cm), **SD** = Seat Depth (cm), **PH Range** = Popliteal Height (cm), **CH** = Chair Height (cm), **BW Range** = Body Weight Range (kg), **DH** = Desk Height (cm), **DC** = Desk Clearance (cm)

All other structural components dimension are the same for the eight ranges of body sizes, as it was designed with the maximum weight of 56kg. Other design outputs generated by the excel interface which is the same for all the anthropometry categories are:

SU Chair Seat Rail: Thickness (w) = 25.4mm; Depth (d) = 94mm

SU Chair Back post /Legs :Thickness (w) = 25.4mm, Depth (d) = 58mm
SU Chair Seat : Seat thickness (w) = 25mm
SU Chair Joint :Thickness (w) = 10mm; Depth (d) = 44.9mm
MU Desk Leg :Thickness (w) = 34mm; Depth (d) = 94.5mm
Desk Joint : Tenor depth = 76.2mm; Tenor width = 17.4mm

4.0 CONCLUSIONS

This study has been able to establish that Wooden Single – User (SU) Chair and Multiple- User (MU) Desk are exclusively in use in Staff School, University of Ibadan. There is a clear mismatch between students' anthropometry and the furniture being offered to them in the Staff School, University of Ibadan, indicating that the existing furniture in the school is ergonomically inadequate. The legs and joints of the furniture in use by the students are poorly designed which leads to frequent repair of legs and joints of the furniture

REFERENCES

Adewole A. N. and A.O. Olorunnisola 2010. "Characteristics of Classroom Chair and Desk in Use in Senior Secondary Schools, Ibadan, Oyo State". Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 1 (2): Pp140-144

Adewole, A N. 2010 "Ergonomic Analysis and Structural Design of Wooden Chairs and Desk for Senior Secondary School Students in Ibadan Land". A Ph.D Thesis in the Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria. 241pp.

Anon 1999. "*Wood Handbook:* Wood as an Engineering Material" Reprinted from USDA Forest Service General Technical Report No. FPL-GTR-113. Forest Products Society.

Bao Z, Eckelman C, Gibson H 1996. "Fatigue Strength and Allowable Design Stresses for Some Wood Composites Used in Furniture. *Holz Roh-Werkstoff* 54 (6), 377-82

Chaffin, D and Anderson G.1991. Occupational Biomechanics. New York: Wiley 1668ppg

Daneshmandi H., Isanezhad A., Hematinezhad M., 2008. "The Effects of Classroom Furniture on Back, Neck, Lumbar and Leg Fatigue in Student". Journal of movement sciences and sports. Pp 37-44.

de Dampierre, F. 2006. "Chairs: A History" A Book. 432pp.

E. Haviarova, C. Eckelman, and Y. Erdi 2001. "Design and Testing of Environmentally Friendly Wooden School Chairs for Developing Countries" Forest Products Journal. 51(3): 58-64.

Hoadley, R. B 1980. "Understanding wood" a craftsman's guide to wood technology. Newtown, CT: The Taunton Press; 1980

Ignacio Castellucci, Maria Antonia Gonçalves b, Pedro M. Arezes: "Ergonomic Design of School Furniture: Challenges for the Portuguese Schools". Applied Human Factor and Ergonomic International Conference Proceedings 2010.

Joanne WY Chung and Thomas KS Wong 2007: Anthropometric evaluation for primary school furniture design.

Khanam, Chanda Nelofer, Mahalakshmi V. Reddy and A. Mrunalini 2006. Designing Students' Seating Furniture for Classroom Environment. J. Hum. Ecol., 20(4): 241-248 (2006)

Lin, Rungtai and Yen- Yu Kang 2005. "Ergonomic Design of Desk and Chair for Primary School Students in Taiwan". A paper presented at id employee conference.

Pakarinen T1999 Success factors of wood as a furniture material. Forest Products Journal. *J.* 49 (9), 79 -85

Percells, Claudia, M.S.N. Manfred-Stommel, and Robert P. Hubbard. 1999. Mismatch of Classroom Furniture and Student Body Dimensions. Society for Adolescent Medicine. 12ppg.

Raja Ariffin, Raja Ghazilla, Zahari Taha, Suraya Kamaruddin and Iskandar Hasanuddin 2010; pilot investigation on the mismatches of classroom furniture and student body dimension in Malaysian secondary schools. Journal of Social Sciences 6 (2): 287-292, 2010

Scott Openshaw et al 2006. "Ergonomics and Design" A Reference Guide

Stevens J, Ahmad M, Ruddell S (1998) Forest products certification: a survey of manufacturers. *Forest* products *Journal*.

Wadso L 1995 Furniture in warm and humid climates. *Building Issues* **7** (2), 1-23

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