

# Mismatch Analysis Between Classroom Chair and Anthropometric Measurements of Mapua University Students

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## Abstract

The research studied the mismatch between anthropometric measurements of senior high school and college students of Mapúa University to the current classroom chair design being used. Each of the two levels was split into two based on sex. In total there were 4 groups compared; the data comprised of SHS male, SHS female, college male, and college female. After performing the Anderson-Darling normality test and one-way ANOVA, the researchers determined that the anthropometric measurements of SHS and college students significantly differ, therefore, two ergonomic classroom chairs were needed separately for the two groups. In performing the mismatch analysis, it was found that the majority of the SHS students and college students have a high mismatch in terms of seat height. The existing seat height of the classroom chair is too high for the students. A proposed design of the chair was then made. In comparing the mismatch of the existing dimensions to the proposed classroom chair, it was found out that the recommended seat height, seat depth, seat width, backrest height, and armrest height improved the overall design of the chair fitted for the majority of the users. The same goes with the backrest height, it was found that the existing chair design is too high for the users. Given this condition, the researchers were able to propose a new dimension for classroom chairs using the anthropometric measurements gathered from the SHS and college students of Mapua University. The mismatch analysis of the proposed chair proved that the recommended seat height, seat depth, seat width, backrest height, and armrest height improved the overall design of the chair fitted for the majority of the users.

## Keywords

Mismatch analysis, anthropometry, ergonomics

## 1. Introduction

According to Sarmiento and Orale, the Philippines' current curriculum called the enhanced basic education program much more known as the K-12 program under the RA 10533 comprises a year in kindergarten, 6 years in elementary, 4 years in junior high school, and 2 years in senior high school (2016). This is a requirement for any student before they can enter college. Therefore, a minimum of 13 years is spent by a majority of Filipino students before they take up a program in college which ranges from a duration of 6 months to 10 years for doctoral degrees. Filipino degree holders spent a great amount of time in classrooms where the learning happens. A basic component of any classroom for that matter is a chair where students will sit down while listening to the lecture. Therefore, classroom chairs are crucial in education and they must be ergonomically designed (Al-Hinail, Mahmood & Shamsuzzoha, 2018)

According to Canadian Centre for Occupational Health and Safety, serious occupational health and safety risks are possible consequences of sitting for a long period. Even though sitting is less strenuous, such an activity does not exempt people from developing injuries. That is why providing an ergonomic chair to students is vital. Also, an ergonomically designed classroom chair is not just important to the student's health but also their overall performance in school. Isedowo stated that a properly designed chair lessens the need of the learner to adjust during lecture, therefore, lessening the diversion of their attention away from their instructor (2012).

In the Philippines, there are very few studies related to ergonomically designed classroom chairs. There is not even a standard chair measurement for students in elementary, high school, and college based on the Filipino population. The closest study related to the topic was only with regards to the assessment of ergonomic mismatch and self-reported pain among college students made by Torres et al. in 2017.

### **1.1. Objectives**

In response to this problem, the study aims to compare the anthropometric measurements of senior high school and college students and determine if there is a significant difference between these dimensions. Also, the researchers will conduct a mismatch analysis to determine the percentage of students who do not fit the dimensions of the existing classroom armchair. Lastly, this research aims to design a standard ergonomic chair that will cater to both senior high school and college students.

## **2. Review of Related Literature**

### **2.1. Ergonomics**

Middlesworth, M. states that Ergonomics is the method of understanding scientific behaviors and disciplines of interactions among humans and other elements of a system. It uses different theories, principles, data, and methods to formulate and design optimal human well-being and overall system performance.

Office Interiors (2019) says that Ergonomics is simply the interaction between humans and the tools they work with. More importantly, it is the act of how humans interact with these tools and their work or activity areas. It was also mentioned that Ergonomics is to fit a task to the human or individual and not the other way around (Fernandez, J. Ph.D. PE, CPE & Goodman M. MD, MPH)

### **2.2. Musculoskeletal Disorders**

According to the Centers for Disease Control and Prevention, it was defined by The Bureau of Labor Statistics of the Department of Labor that MSDs or Musculoskeletal Disorders are musculoskeletal systems and connective tissue diseases and disorders. These are caused by the event or exposure to different bodily reactions (e.g., bending, twisting, overexertion, repetitive motion).

Meanwhile, a study conducted by Roman-Liu D. (2014) came to a conclusion where the concepts of assessing risk in different methods can be used to develop solutions. This leads to a deeper comprehension wherein appropriate methods can be implemented for all work tasks and all parts of the body.

### **2.3. Male and Female Anthropometric Measurements**

The American Academy of Pediatrics mentions that puberty is composed of a clear sequence of stages. This affects the skeletal, muscular, reproductive, and almost all other systems in the body. Although change is present, these changes during puberty tend to be more gradual and steadier. Such changes in body composition may be in height, weight, etc.

### **2.4. Anthropometric Calculations Basis**

It was mentioned by Panagiotopoulou et al. (2004) that a mismatch for the Seat Height is defined when the gathered measurement is either greater than 95% or less than 88% of the popliteal height. This would be later adjusted by an additional 2cm for the standard shoe height.

Gouvali and Boudolos (2006) state that the mismatch for the Seat Height is defined when the gathered measurement is either greater than 99% or 80% of the buttock popliteal length.

Meanwhile, Castellucci et.al. (2010) defines a mismatch in Seat Width when the measurement for hip breadth is narrower or less than the seat width.

For this study, the Arm Rest Height is based on the reference of the Seat to Desk Height criteria for measurement by Bendak et al., (2013), and Castellucci et al., (2010). Wherein a mismatch is defined when the Sitting Elbow height is either less than the recorded Sitting Elbow Height or greater than an additional value of 5 cm to the Sitting Elbow Height.

For the Backrest Height, Castellucci et.al. (2010) defines a mismatch when the measurement is either below 60% or higher than 80% of the given Sitting Shoulder Height measurement. This criterion was from studies conducted by Afzan, et al., (2012), Agha (2010), Dianat, et al., (2013), and Gouvali and Boudolos (2006).

Previous research studies and related literature evaluated the level of mismatch between the anthropometric measurements of a given population and the dimensions of various furniture such as desks and chairs. However, there remains a paucity in studies that focused on mismatch analysis that is specific for classroom armchairs. Moreover, only a few research articles regarding this topic were conducted in the Philippines.

## 2. Methodology

The input for the present study is the anthropometric measurements of senior high school and college students as well as the existing dimensions of the classroom armchair used in the university. After then, the data were statistically treated using the Anderson-Darling normality test and a one-way analysis of variance. Moreover, a mismatch analysis between the anthropometric measurements and armchair dimensions was conducted. Finally, the outcome of this study is the ergonomically designed classroom armchair that caters to both senior high school and college students.

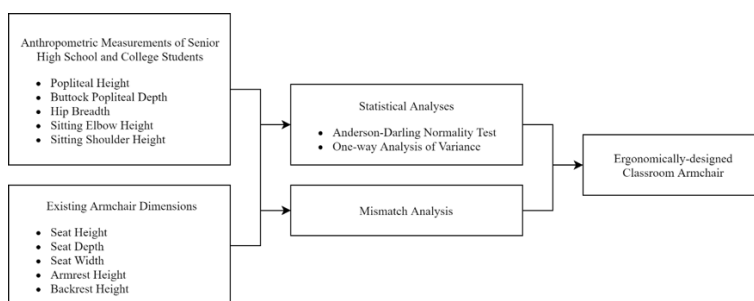


Figure 1. I-P-O Framework of the Study

### 2.2 Respondents of the Study

The participants of the present study were senior high school and college students from Mapua University, Intramuros, Manila. Since there is only one existing armchair for both levels, this research determined whether there is a significant difference between the anthropometric measurements of the students. With this, the researchers would know whether to design a separate ergonomic armchair that would fit both senior high school and college students.

### 2.3 Anthropometric Measurements

Primarily, five dimensions of the existing armchair were obtained in this research: seat height, seat depth, seat width, armrest height, and backrest height. Table 1 shows the data for these measurements.

Table 1. Dimensions of the Existing Armchair used by the University

Dimensions	Actual Measurement (cm)
Seat Height	48
Seat Depth	42
Seat Width	46
Armrest Height	23
Backrest Height	45

Moreover, five anthropometric measurements were measured in the study: popliteal height (PH), buttock popliteal depth (BPD), hip breadth (HB), sitting elbow height (SEH), and sitting shoulder height (SSH).

### 2.4 Statistical Treatment of Data

For the anthropometric measurements, the Anderson-Darling normality test was conducted to eliminate outliers and minimize errors in data. The upper and lower outliers in the probability plot were deleted until the AD Score is approximately below 2.00.

For the statistical analysis, a one-way Analysis of Variance (ANOVA) was performed to test whether there is a significant difference in the anthropometric measurements by gender and by level. The comparisons were between male and female senior high school students, male and female college students, senior high school and college male students, and senior high school and college female students. The tests comparing the male and female students from each level were essential in the grouping of data, while the comparisons between the senior high school and college students were needed to determine if a separate ergonomic armchair for the two levels was needed.

## 2.5 Mismatch Analysis

### 2.5.1 Seat Height (SH)

If the dimension of the seat height is either less than 88% or greater than 95% of a student's popliteal height, a mismatch is established. Hence, the equation defining the match criterion is shown in Equation 1 and is adopted from Rosyidi et al. (2016):

$$0.88 (PH + 2) \leq SH \leq 0.95 (PH + 2) \quad (1)$$

### 2.5.2 Seat Depth (SD)

Concerning the seat depth, Equation 2 is used as a match criterion (Gouvali and Boudolos, 2006):

$$0.8BPD \leq SD \leq 0.99BPD \quad (2)$$

### 2.5.3 Seat Width (SW)

According to Castelluci et al. (2010), a mismatch is established if the hip breadth of the students is narrower than the dimensions of the seat width, as shown in Equation 3:

$$HB < SW \quad (3)$$

### 2.5.4 Armrest Height (AH)

For the armrest height, the mismatch is based on Chaffin and Anderson's principles (1991) as stated by Castelluci et al. (2010). Hence, Equation 4 shows the criterion:

$$SEH \leq AH \leq SEH + 5 \quad (4)$$

### 2.5.5 Backrest Height

The mismatch criterion for the backrest height is also adapted from Castelluci et al. (2010):

$$0.6SSH \leq BH \leq 0.8SSH \quad (5)$$

## 3. Results and Discussion

### 3.1. Statistical Treatment of Data

Before the one-way analysis of variance, the Anderson-Darling normality test was performed to ensure that no outliers affected the statistical treatment of data. Table 2 summarizes the results of the normality test.

Table 2. Result of Normality Test

DIMENSION	SHS					
	Male			Female		
	N	AD	p-value	N	AD	p-value
Popliteal Height	129	1.686	<0.005	132	1.331	<0.005
Buttock-popliteal depth	130	1.064	0.008	130	2.039	<0.005
Hip Breadth	122	1.14	0.005	129	1.456	<0.005
Sitting elbow height	129	1.426	<0.005	130	0.961	<0.005
Sitting shoulder height	125	0.682	0.073	130	0.952	0.016
DIMENSION	College					
	Male			Female		
	N	AD	p-value	N	AD	p-value
Popliteal Height	49	0.947	0.015	59	0.919	0.018
Buttock-popliteal depth	49	0.69	0.067	61	0.179	0.914
Hip Breadth	48	0.954	0.015	62	0.297	0.581
Sitting elbow height	47	0.516	0.181	59	0.478	0.227
Sitting shoulder height	48	0.438	0.284	61	0.223	0.818

Consequently, one-way Analysis of Variance (ANOVA) was performed to perform comparisons between male and female senior high school students, male and female college students, senior high school and college male students, and senior high school and college female students.

With regards to the comparisons by gender, a significant difference between male and female anthropometric measurements from both levels was established. Tables 3 and 4 summarize the results of the ANOVA.

Table 3. T-Test Results for Male and Female Senior High School Students

DIMENSION	SHS						p-value	Remarks
	MALE			FEMALE				
	N	Mean	SD	N	Mean	SD		
Popliteal Height	128	45.93	2.08	132	44.62	2.98	0.00	Significant
Buttock-popliteal depth	130	44.89	3.85	132	43.88	3.45	0.03	Significant
Hip Breadth	121	34.74	4.17	129	34.07	4.59	0.23	Not Significant
Sitting elbow height	129	21.83	4.06	130	24.92	4.77	0.00	Significant
Sitting shoulder height	125	47.84	4.07	130	39.22	5.51	0.00	Significant

Table 4. T-Test Results for Male and Female College Students

DIMENSION	COLLEGE						p-value	Remarks
	MALE			FEMALE				
	N	Mean	SD	N	Mean	SD		
Popliteal Height	49	43.68	2.23	59	40.24	2.17	0.00	Significant
Buttock-popliteal depth	49	45.83	3.49	61	43.40	3.31	0.00	Significant
Hip Breadth	48	34.12	4.12	62	34.38	4.14	0.75	Not Significant
Sitting elbow height	47	23.83	3.08	59	24.38	2.78	0.34	Not Significant
Sitting shoulder height	48	49.42	4.58	61	45.66	3.49	0.00	Significant

Concerning the comparisons between the two levels, a significant difference between the anthropometric measurements of the senior high school and college students from both genders was proven, and the results are shown in Tables 5 and 6.

Table 5. T-Test Results for Senior High School and College Male Students

DIMENSION	MALE						p-value	Remarks
	SHS			COLLEGE				
	N	Mean	SD	N	Mean	SD		
Popliteal Height	128	45.93	2.08	49	43.68	2.23	0.00	Significant
Buttock-popliteal depth	130	44.89	3.85	49	45.83	3.49	0.12	Not Significant
Hip Breadth	121	34.74	4.17	48	34.12	4.12	0.38	Not Significant
Sitting elbow height	129	21.83	4.06	47	23.83	3.08	0.00	Significant
Sitting shoulder height	125	47.84	4.07	48	49.42	4.58	0.04	Significant

Table 6. T-Test Results for Senior High School and College Female Students

DIMENSION	FEMALE						p-value	Remarks
	SHS			COLLEGE				
	N	Mean	SD	N	Mean	SD		
Popliteal Height	132	44.62	2.98	59	40.24	2.17	0.00	Significant
Buttock-popliteal depth	130	43.88	3.45	61	43.40	3.31	0.35	Not Significant
Hip Breadth	129	34.07	4.59	62	34.38	4.14	0.65	Not Significant
Sitting elbow height	130	24.92	4.77	59	24.38	2.78	0.34	Not Significant

Sitting shoulder height	130	39.22	5.51	61	45.66	3.49	0.00	Significant
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Based on the statistical treatment of data, there were indeed significant differences among all comparisons by gender and by level. With this, with regards to the comparisons by gender, the significant result from the one-way analysis of variance indicated that the anthropometric data for male and female students must be in separate groups. In addition, with regards to comparisons by level, the significant difference between the measurements suggested that a separate ergonomic classroom chair must be designed for both senior high school and college students.

#### 4.2 Mismatch Analysis between Anthropometric Measurements and Existing Armchair

Following the statistical treatment of data, a mismatch analysis between the anthropometric measurements of both male and female students at the senior high school and college levels was performed. The frequencies and percentages of the too high (H), too low (L), and matched (M) dimensions were evaluated per armchair dimension; the mismatch criterion was all based on the equations adopted from the previous studies. Tables 7, 8, and 9 summarize the results of the analysis.

Table 7. Mismatch Analysis between the Male Students and the Existing Armchair

Dimensions		Senior Highschool		College	
		Frequency	Percentage	Frequency	Percentage
Seat Height	Too High (H)	115	90%	49	100%
	Too Low (L)	0	0%	0	0%
	Match (M)	13	10%	0	0%
	TOTAL	128	100%	49	100%
Seat Depth	Too Shallow (S)	3	2%	3	6%
	Too Deep (D)	30	23%	9	18%
	Match (M)	97	75%	37	76%
	TOTAL	130	100%	49	100%
Seat Width	Too Narrow (N)	0	0%	0	0%
	Too Wide (W)	0	0%	0	0%
	Match (M)	121	100%	48	100%
	TOTAL	121	100%	48	100%
Backrest Height	Too High (H)	40	31%	45	94%
	Too Low (L)	0	0%	0	0%
	Match (M)	87	69%	3	6%
	TOTAL	127	100%	48	100%
Armrest Height	Too High (H)	14	11%	1	2%
	Too Low (L)	44	34%	31	66%
	Match (M)	71	55%	15	32%
	TOTAL	129	100%	47	100%

Table 8. Mismatch Analysis between the Female Students and the Existing Armchair

Dimensions		Senior Highschool		College	
		Frequency	Percentage	Frequency	Percentage
Seat Height	Too High (H)	120	91%	59	100%
	Too Low (L)	0	0%	0	0%
	Match (M)	12	9%	0	0%
	TOTAL	132	100%	59	100%
Seat Depth	Too Shallow (S)	0	0%	0	0%
	Too Deep (D)	42	32%	26	43%
	Match (M)	88	68%	35	57%
	TOTAL	130	100%	61	100%
Seat Width	Too Narrow (N)	0	2%	0	0%
	Too Wide (W)	42	0%	0	0%
	Match (M)	88	98%	62	100%

	TOTAL	129	100%	62	100%
Backrest Height	Too High (H)	130	100%	61	100%
	Too Low (L)	0	0%	0	0%
	Match (M)	0	0%	0	0%
	TOTAL	130	100%	61	100%
Armrest Height	Too High (H)	3	2%	0	0%
	Too Low (L)	75	58%	38	64%
	Match (M)	52	40%	21	36%
	TOTAL	130	100%	59	100%

Table 9. Summary of Mismatch Analysis for the Existing Armchair

Dimensions		Senior Highschool			College		
		Frequency (Male)	Frequency (Female)	Total	Frequency (Male)	Frequency (Female)	Total
Seat Height	Too High (H)	115	120	235	49	59	108
	Too Low (L)	0	0	0	0	0	0
	Match (M)	13	12	25	0	0	0
Seat Depth	Too Shallow (S)	3	0	3	3	0	3
	Too Deep (D)	30	42	72	9	26	35
	Match (M)	97	88	185	37	35	72
Seat Width	Too Narrow (N)	0	0	0	0	0	0
	Too Wide (W)	0	42	42	0	0	0
	Match (M)	121	88	209	48	62	110
Backrest Height	Too High (H)	40	130	170	45	61	106
	Too Low (L)	0	0	0	0	0	0
	Match (M)	87	0	87	3	0	3
Arm Rest Height	Too High (H)	14	3	17	1	0	1
	Too Low (L)	44	75	119	31	38	69
	Match (M)	71	52	123	15	21	36

For the mismatch analysis between senior high school students and the existing armchair, the greatest mismatch problems were observed in the seat height, backrest height, and armrest height. Based on the mismatch criterion, the seat height was too high for 235 students, and there were only 25 matches. Also, the backrest height was too high for 170 of them, and only 87 people were matched. The armrest height was too high for 17 people and too low for 119 students, while 123 people were matched.

On the other hand, there is also a moderate mismatch concerning the seat depth and seat width, the seat depth was too shallow for 3 and too deep for 72 students, but there were 185 matches observed. Meanwhile, the seat width was too wide for only 42 students but was still matched for 209 people.

On the other hand, for the mismatch analysis between the male and female college students and the existing armchair, the greatest mismatch frequencies, and percentages were also noticed in the seat height, backrest height, and armrest height. Based on the mismatch criterion, the seat height was too high for 108 students, and there were no recorded matches. Moreover, the backrest height was too high for 106 people, and only 3 people had matched the dimensions. The armrest height was too high for 1 person and was too low for 69 students, while 36 people were matched. On the other hand, for the mismatch concerning the seat depth and seat width, the seat depth was too shallow for 3 and too deep for 35 students, but there were 72 matches. For the seat width, there were no mismatches seen.

### 4.3 Anthropometric Percentiles

With reference to the calculated means and standard deviations of the anthropometric measurements, the anthropometric percentiles were obtained.

Tables 10 and 11 are the tabulated data gathered for the Anthropometric Percentiles for both SHS and College students. These tables are for reference for the proposed new chair dimensions. The 5th Percentile represents the minimum value and was calculated using the formula: Mean – 1.645SD, while the 95th Percentile represents the maximum value and was computed using the formula: Mean + 1.645SD.

Table 10. Anthropometric Percentiles for Senior High School Students

SHS								
Anthropometric Measurements	MALE				FEMALE			
	Mean	SD	5th %	95th %	Mean	SD	5th %	95th %
Popliteal Height	46	2.08	43	49	45	2.98	40	50
Buttock-popliteal depth	45	3.85	39	51	44	3.45	38	50
Hip breadth	35	4.17	28	42	34	4.59	27	42
Sitting elbow height	24	2.12	20	27	25	2.16	21	28
Sitting shoulder height	48	4.12	41	55	43	4.41	36	51

Table 11. Anthropometric Percentiles for College Students

COLLEGE								
Anthropometric Measurements	MALE				FEMALE			
	Mean	SD	5th %	95th %	Mean	SD	5th %	95th %
Popliteal Height	44	2.23	40	47	40	2.17	37	44
Buttock-popliteal depth	46	3.49	40	52	43	3.31	38	49
Hip breadth	34	4.12	27	41	34	4.14	28	41
Sitting elbow height	24	3.08	19	29	24	2.78	20	29
Sitting shoulder height	49	4.58	42	57	46	3.49	40	51

### 4.3 Proposed Chair Dimensions

Based on the anthropometric percentiles for senior high school and college students, two separate classroom armchairs were designed in this study. The references for the seat height, seat depth, armrest height, and backrest height were the minimum percentiles, while the reference for the seat width was the maximum percentile. Tables 12 and 13 summarize the proposed dimensions for the ergonomic classroom armchair.

Table 12. Proposed Chair Dimensions for Senior High School

Chair Dimension	Anthropometric Reference	Percentiles	Gender	Recommended Measurements
Seat height	Popliteal Height + shoe heel	5th	Female	42 cm
Seat depth	Buttock-popliteal depth	5th	Female	38 cm
Seat width	Hip breadth	95th	Male	42 cm
Arm rest height	Sitting elbow height	5th	Male	20 cm
Backrest height	Sitting shoulder height	5th	Female	38 cm

Table 13. Proposed Chair Dimensions for College Students

Chair Dimension	Anthropometric Reference	Percentiles	Gender	Recommended Measurements
Seat height	Popliteal Height + shoe heel	5th	Female	39 cm
Seat depth	Buttock-popliteal depth	5th	Female	38 cm
Seat width	Hip breadth	95th	Male	41 cm
Armrest height	Sitting elbow height	5th	Male	19 cm
Backrest height	Sitting shoulder height	5th	Male	40 cm



For the armchair designed for senior high school students, the dimensions must be 42 cm for the seat height, 38 cm for the seat depth, 42 cm for the seat width, 20 cm for the armrest height, and 38 cm for the backrest height. On the other hand, for the armchair proposed for the college students, the measurements must then be 39 cm for the seat height, 39 cm for the seat depth, 41 cm for the seat width, 19 cm for the armrest height, and 40 cm for the backrest height. All of the aforementioned dimensions were proposed to fit their corresponding populations.

#### 4.4 Mismatch Analysis between Anthropometric Measurements and Proposed Armchair

Table 14. Summary of Mismatch Analysis between SHS and Proposed Armchair

SHS ARMCHAIR							
Dimensions		Existing			Proposed		
		Frequency (Male)	Frequency (Female)	Total	Frequency (Male)	Frequency (Female)	Total
Seat Height	Too High (H)	115	120	235	21	22	43
	Too Low (L)	0	0	0	0	6	6
	Match (M)	13	12	25	107	104	211
Seat Depth	Too Shallow (S)	3	0	3	12	14	26
	Too Deep (D)	30	42	72	15	14	29
	Match (M)	97	88	185	103	102	205
Seat Width	Too Narrow (N)	0	0	0	0	0	0
	Too Wide (W)	0	0	0	0	0	0
	Match (M)	121	130	251	121	130	251
Backrest Height	Too High (H)	40	55	95	4	8	12
	Too Low (L)	0	0	0	0	2	2
	Match (M)	87	75	162	123	120	243
Arm Rest Height	Too High (H)	14	3	17	0	18	18
	Too Low (L)	44	75	119	46	32	78
	Match (M)	71	52	123	83	79	162

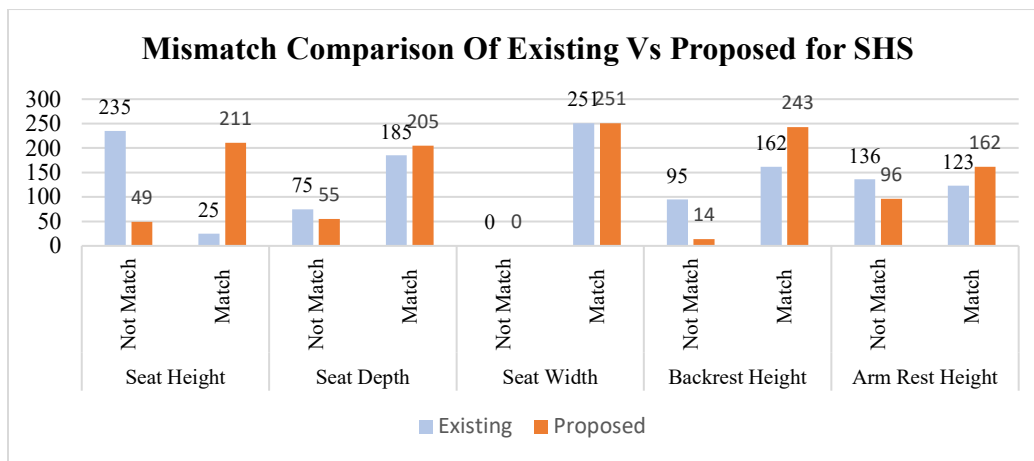


Figure 4. Mismatch Comparison of Existing Vs Proposed Armchair for Senior High School Students

This table and figure show a comparison of the gathered results between the existing and proposed measurements for the SHS students. It can be seen that upon comparing the number of matched frequencies between the existing and proposed columns, there is either a significant increase or no increase at all. This means that there is a presence of an improvement index when it comes to the proposed measurements for Senior High School Students both male and female.

Table 15. Summary of Mismatch Analysis between College Students and Proposed Armchair

COLLEGE ARMCHAIR							
Dimensions		Existing			Proposed		
		Frequency (Male)	Frequency (Female)	Total	Frequency (Male)	Frequency (Female)	Total
Seat Height	Too High (H)	49	59	108	14	17	31
	Too Low (L)	0	0	0	1	3	4
	Match (M)	0	0	0	34	39	73
Seat Depth	Too Shallow (S)	3	0	3	3	3	6
	Too Deep (D)	9	26	35	0	8	8
	Match (M)	37	35	72	46	50	96
Seat Width	Too Narrow (N)	0	0	0	0	0	0
	Too Wide (W)	0	0	0	0	0	0
	Match (M)	48	62	110	48	62	110
Backrest Height	Too High (H)	45	44	89	0	1	1
	Too Low (L)	0	0	0	9	7	16
	Match (M)	23	11	34	39	53	92
Arm Rest Height	Too High (H)	1	0	1	3	2	5
	Too Low (L)	31	38	69	19	18	37
	Match (M)	15	21	36	25	39	64

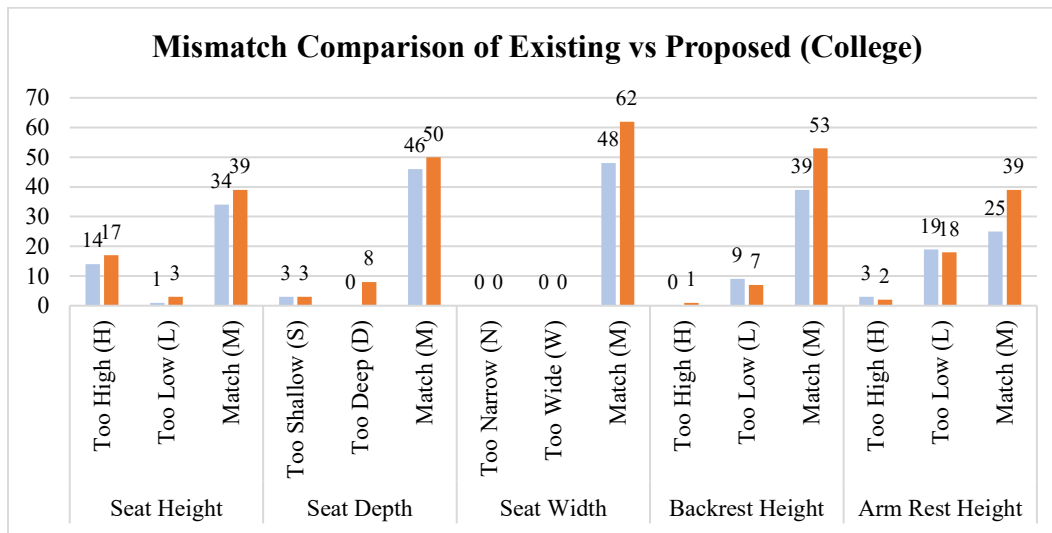


Figure 5. Mismatch Comparison of Existing Vs Proposed Armchair for College Students

On the other hand, the table and figure show a comparison of the gathered results between the existing and proposed measurements for the college students. It can be seen that comparing the number of matched frequencies between the existing and proposed columns, there is either a significant increase or no increase at all. Similar to the mismatch comparison for senior high school students, there is a presence of an improvement index when it comes to the proposed measurements for college students, both male and female.

#### 4.4 Mismatch Comparisons between the Existing and Proposed Armchair

Table 16. Summary of Mismatch Comparisons between the Existing and Proposed Armchair

Dimensions		SHS		% Improvement	College		% Improvement
		Existing	Proposed		Existing	Proposed	
Seat Height	Not Match	235	49	<b>88.15%</b>	108	35	<b>73%</b>
	Match	25	211		0	73	
Seat Depth	Not Match	75	55	<b>10.81%</b>	38	14	<b>33.33%</b>
	Match	185	205		72	96	
Seat Width	Not Match	0	0	N/A	0	0	N/A
	Match	251	251		110	110	
Backrest Height	Not Match	95	14	<b>50.00%</b>	89	17	<b>171%</b>
	Match	162	243		34	92	
Arm Rest Height	Not Match	136	96	<b>31.70%</b>	70	42	<b>77.78%</b>
	Match	123	162		36	64	

Table 16 represents a summary of the gathered data from the mismatch analyses of the existing versus the proposed measurements. The improvement percentages show how much improvement will happen when the proposed measurement is followed instead of the actual or existing measurements. With reference to the results, it can be seen that the proposed armchair provides improvements for the seat height, seat depth, backrest height, and armrest height. wherein the greatest improvement would be the seat height (88.15%) for the SHS students and the backrest height for college students (171%). With regards to the seat width, both the existing and proposed armchair fit all students. Overall, the proposed classroom ergonomic chair is perceived to be more ideal for the students.

#### 4. Conclusion

The researchers were able to identify that there is a significant difference in measurements between male and female senior high school students as well as male and female college students. Furthermore, measurements of both female populations of senior high and college, and both male populations of senior high school and college students showed significant differences as well. Hence, there is a need to produce chairs with different armchair measurements for the two distinct levels. The researchers were also able to suggest standard measurements for the five vital chair dimensions identified for the research. It was later found out that the recommended seat height, seat depth, seat width, backrest height, and armrest height improved the overall design of the chair fitted for the majority of the users.

With this, the researchers suggest future investigators have more sample sizes for better accuracy since the more people assessed, the more accurate the suggested standard measurements for the chairs will be. Also, it is recommended to eliminate outliers more precisely and accurately. Hence, in the Anderson-Darling test, future studies must not only dwell on the AD score but rather focus on the p-value of the normality test. Lastly, future studies could explore the possibility of considering the average anthropometric measurements from the participants instead of having the minimum and maximum percentiles as the basis for designing and proposing chair dimensions. In this way, the said dimensions could match more students.

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