AN ERGONOMIC CLASSROOM DESIGN APPLICATION at a UNIVERSITY in TURKEY

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ABSTRACT

Purpose: Ergonomics is a branch of science that uses scientific methods to improve the workplaces and environments to maximize the comfort and safety of humans. In this study, we suggest new classroom furniture dimensions defining the problems about environmental factors in the classrooms such as noise, light, air conditioning, or temperature by considering the real data obtained from a university.

Methodology: A questionnaire is prepared to determine the most complained problems by the students about the classroom furniture and environment. A total of 219 students participate in the questionnaire at a university in Ankara, Turkey. The dissatisfaction scores are evaluated for each question to define the most complained problems.

Findings: The results show that most of the students are not satisfied with the use of tablet-armed chairs due to different reasons. To solve the problems, the anthropometric measurements of the students are evaluated. Based on these measurements, new furniture dimensions are suggested and compared with the existing ones.

Originality: The ergonomic classroom design in this study is an original work that is designed according to the data obtained from the university in concern. It is aimed that the implemented methodology and the comprehensive literature review for the ergonomic classroom design in this study can be a source of inspiration for the educational institutions.

Keywords: Educational Ergonomics, Facility Design, Statistical Anthropometric Assessment, Musculoskeletal Disorders, Classroom Furniture.

JEL Codes: C13, C60, C61.

TÜRKİYE'DEKİ BİR ÜNİVERSİTEDE ERGONOMİK BİR SINIF TASARIMI UYGULAMASI

ÖZET

Amaç: Ergonomi, insanın konfor ve güvenliğini en üst düzeye çıkarmak adına işyerleri ve diğer ortamları geliştirmek için bilimsel yöntemleri kullanan bir bilim dalıdır. Bu çalışmada, bir üniversiteden elde edilen gerçek veriler dikkate alınarak, sınıflardaki gürültü, ışık, iklimlendirme, sıcaklık gibi çevresel faktörlerle ilgili sorunları tanımlayan yeni derslik mobilya boyutları önerilmiştir.

Yöntem: Bu çalışmada, öğrenciler tarafından sınıf eşyası ve ortamı açısından en çok şikayet edilen problemlerin belirlenmesi için bir anket hazırlanmıştır. Ankara'daki bir üniversitede toplam 219 öğrenci ankete katılmıştır. En çok şikayet edilen problemlerin belirlenmesi için her bir soru için memnuniyetsizlik puanları hesaplanmıştır.

Bulgular: Sonuçlar, öğrencilerin çoğunun farklı sebeplerden dolayı kolçaklı sandalyelerden memnun olmadıklarını göstermiştir. Problemleri çözmek için öğrencilerin antropometrik ölçüleri hesaplanmıştır. Bu ölçülere bağlı olarak, önerilen eşya boyutları belirtilmiş ve mevcut hali ile kıyaslanmıştır.

Özgünlük: Bu çalışmadaki ergonomik sınıf tasarımı çalışma yapılan üniversiteye özgün olarak elde edilen verilerle yapılmış bir çalışmadır. Uygulanan metodolojinin ve kapsamlı literatür araştırmasının başka eğitimsel kurumlar için bir ilham kaynağı olabilmesi hedeflenmiştir.

Anahtar Kelimeler: Eğitimsel Ergonomi, Tesis Tasarımı, İstatistiksel Antropometrik Değerlendirme, Kas-İskelet Sistemi Bozukluğu, Derslik Eşyası.

JEL Kodları: C13, C60, C61.

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1. INTRODUCTION

The word “ergonomic” comes from the Greek word “ergon” meaning “work” and “nomos” meaning “law” (Sluchak, 1992). It is indicated in the study of Rowanı and Wright (1994) that ergonomics deals with interacting components, which consist of the task, the worker, the workspace, and the physical/ organizational work environment. The same study indicates that the objective of ergonomics is providing a good fit between tasks and workers to maximize productivity, safety, and comfort. Therefore, another purpose of ergonomics can be defined as providing human happiness and satisfaction.

The study areas of anatomy, anthropology, physiology, psychology, and engineering sciences are also the study areas of ergonomics (Önder et al., 2013). Because ergonomics considers the relations between the work area and humans, another area of science that needs to be mentioned in this context is anthropometry. The definition of anthropometry is based on the Greek words “Anthropos” and “metron”, which mean ”human” and “measurement”, respectively (Dönmez, 2008). The objective of anthropometry can be defined as determining the body proportions and size by evaluating body width, length, circumference, and skinfold thickness (Wang et al., 2000).

As it is known, ergonomics is a multidisciplinary field of research, which is aimed at revealing the basic laws of system efficiency and human-environment compatibility by considering the anatomical characteristics, the physiological capacities, and the tolerances of people in the face of organic and psychosocial stresses. These stresses can be caused by the effects of all factors in the working environment. In other words, ergonomics aims not only to increase productivity but also to reveal the scientific data required for the person to work in the most comfortable and optimal conditions.

The study topics of ergonomics, which have a very wide working area, can be listed as the following (Fığlalı, 2009).

- Body posture and movements (working by sitting or standing, lifting, carrying, pushing or pulling),
- Physical environmental conditions (lighting, noise, vibration, climate, ventilation, effects of harmful substances and precautions that can be taken),
- Work organization (scheduling work and rest time, shift arrangements, job enrichment, job expansion, and job rotation),
- Duty descriptions, and analysis (designing works and tasks, analyzing the conformity of existing tasks with the ergonomic criteria, and assigning the correct person for the correct duty),
- Mental work and information (cognitive factors, mental workload and measurement, and human-computer interaction).

According to educators, learning may occur in an environment that is appropriate for physical, social, and psychological aspects. For an effective education, it is necessary to organize the environment in compliance with the learning-teaching activities. This situation requires that the various interaction dimensions between the environment and the individual should be organized and directed in the direction of the educational objectives. People can only succeed in an ergonomic working environment, which they love. Therefore, working in an appropriate environment makes learning easier. In the study of Smith (2012), it is concluded that the ergonomic design properties of classrooms noticeably influence the learning of students.

The environmental performance factors are classified as technical, functional, and behavioral aspects (Demirkan, 1995). When ergonomics is considered for the educational environments especially, it is an applied scientific discipline that should be used in the arrangement of the buildings, classrooms, and laboratories. By these ergonomic arrangements, the students can be educated in a better humanistic environment by increased productivity (Önder et al., 2013). The physical environment of the classrooms in the universities, which directly influences the success of the students, is affected by some factors such as furniture dimension, air conditioning, colorization, lighting, temperature, noise (acoustics), and cleanliness. Because these factors play an important role in the learning-teaching processes, they should be analyzed and improved.

In this study, according to the questionnaire that is prepared to determine the most complained problems by the students about the classroom furniture and environment, the dissatisfaction scores are evaluated. In this study, depending on the anthropometric measurements, appropriate furniture dimensions are suggested and the comparison between the suggested and standard dimensions is presented. It is aimed that the implemented methodology and the comprehensive literature review for the ergonomic classroom design can be a source of inspiration for the other educational institutions.

The remainder of this study is structured as follows. A summary of the literature is given in Section 2. The analysis of the questionnaire is presented in Section 3. The anthropometric measurements are given in Section 4. Finally, the conclusions are discussed in Section 5. Since the study is carried out by using the data obtained from the university and the statistical methods complying with this data this study contributes to the literature different from the other studies.

2. LITERATURE REVIEW

Many studies in the literature focus on the ergonomic design of classrooms and their effects on the human body. The incompatibility between the anthropometric measures of the students and the furniture dimensions of the classrooms is reported in many studies among different countries (Kahya, 2018; Gouvali and Boudolos, 2006; Panagiotopoulou et al., 2004; Parcells et al., 1999). The awkward and uncomfortable body postures because of the mismatched furniture dimensions can decrease the learning interests of the students (Hira, 1980). The study of Savanur (2007) underlines that these mismatches can also create some health problems such as musculoskeletal and postural dysfunctions. The studies of Grimmer and Williams (2000) and Grimmer and Milanese (2004) indicate that the mismatch between furniture dimensions and the anthropometry of the students is the most significant factor for suffering from low back pain. Therefore, it is critical to analyze the mismatches between the anthropometric measures of the students and the dimensions of the classroom furniture like a desk and chair to minimize the mentioned problems.

Khoshabi et al. (2020) aim to rank and compare various furniture types of classrooms depending on the mismatch between furniture dimensions and anthropometric measures of university students. For this objective, a multi-criteria decision-making approach is developed and used as a solution methodology. A total of ten anthropometric measures from 111 participants and eight dimensions of furniture from four chair types are considered. In the study, the mismatch equations and the Simple Additive Weighting technique are used to analyze mismatches and solve multi-criteria decision-making problems, respectively. Then, the dimensions that have the highest and lowest levels of the match and mismatch, respectively, are evaluated. It is concluded that the seat width has the lowest mismatch. Additionally, the sensitivity analysis is implemented by changing criteria weights and using different multi-criteria decision-making techniques to compare the results in the study.

Fidelis et al. (2020) emphasize that the students spend their time mostly in the classrooms in sitting positions, so the improper furniture in the classrooms can cause irritation, discomfort, and musculoskeletal problems. The objective of the study is to search for the mismatches between the anthropometric measures of the students and furniture dimensions in the chosen classrooms by a case study. The results of the study show that the existing furniture in the classrooms is not suitable for the anthropometric measures of the many students.

Castellucci et al. (2010) underline that students spend too much time sitting down in a day. The purpose of their study is to compare the sizes of furniture and anthropometric characteristics of students to determine the possible mismatches. In the study, different anthropometric measures are considered. These are buttock-popliteal length, stature, popliteal height, hip width, subscapular height, thigh thickness, and elbow height. To evaluate the furniture of the classrooms, a match criterion equation is used. With the help of this equation, the incompatibilities between furniture dimensions and anthropometric characteristics of students are evaluated. The results of the study show that there are many mismatches between them. Jayaratne and Fernando (2009) state that the arrangement of seating is a significant ergonomic issue of the classroom and the critical seating properties contain the desk and chair features, and also their

locations to the blackboard. They mention that the musculoskeletal pain of the students is the most significant negative effect because of mismatched ergonomics. In the study, a case study for a school is implemented to determine these mismatches. The results of the study show that there are many incompatibilities between the body characteristics of the chosen students and seating properties.

A comparison of dimensions of school furniture and dimensions of students is considered in primary school by Panagiotopoulou et al. (2004). The objective of the study is to determine whether the furniture is designed well and provides proper posture for sitting at school by considering children's dimensions. The considered dimensions of the human body are knee height, shoulder height, popliteal height, upper arm height, elbow height, and buttock–popliteal length. These dimensions are measured for different kinds of desks and chairs in the classrooms. The comparison is made between dimensions of the furniture and anthropometric measures to determine the incompatibilities in the study. The results of the study show the incompatibilities, which have unfavorable impacts on the posture of students.

The temperature of the classroom environment is a factor that affects the students physically and psychologically. Excessively hot or cold environments disrupt the concentration of the students and decrease the performance of the learning. Dönmez (2008) indicates that the temperature between 15.6-20 °C is suitable for workshops that require physical activity and the suitable temperature range for the classroom environment is between 19.7-22.8 °C. In the same study, it is underlined that the relative humidity should be at most 70%, and the ideal airflow is accepted to be suitable around 150 mm/sec for educational environments. Additionally, it is indicated in the same study that when the airflow gets to 510 mm/sec., the environment is accepted to be breezy, and when the airflow decreases to 100 mm/sec., the environment is called to be airless. Especially, the classrooms, where computers are used extensively, and crowded classes should be ventilated more frequently.

The main goal of lightening the classroom is to provide the appropriate condition for education. Lighting is a crucial environmental factor that directly affects human psychology. Yalçınkaya (2012) states that the working conditions that benefit from daylight as much as possible affect the productivity of the students in a positive way. The same study underlines that enough luminous intensity, equal lightening spread, correct lightening direction and shading, protection from light reflections, proper light qualification, and fixed lighting are important for good lighting. It is proved that the classrooms that do not have windows have negative effects on the learning performance of the students (Altan, 1989). Besides, the lighting should be made by the use of daylight within the bounds of possibility rather than artificial lighting (Önder et al., 2013).

Noise can be defined as an unwanted sound in general and the loud noise may cause pain in the ears. This annoying noise can decrease the learning performance of the students. Yalçınkaya (2012) underlines that the suggested noise level for the educational environments is limited by 30 dB. On the other hand, the study of Dönmez (2008) indicates that the tolerable sound level is between 40 and 60 dB (decibel) for normal working conditions, and the maximum admissible noise level is 90 dB on condition that it is not continuous. The same study underlines that the noise in the classroom environment has some negative physical and psychological effects on students such as hearing loss, boredom, absent state, inattention, psychomotor disorders (a problem in regular sleep pattern, side effects for the unconscious mind), and increase in heart rate. The most important factor that plays role in classroom acoustic is the resonance and the long resonance time may have a negative effect on the understandability of the voice (Yalçınkaya, 2012).

Colorization is an important factor that affects the neural system in either positive or negative aspects. Therefore, colorization can be a factor that encourages learning for the students (Önder et al., 2013). However, this factor sometimes is not adequately taken into consideration in environmental conditions. Yalçınkaya (2012) emphasizes that this neglect may cause monotony, boredom, tiredness, and loss of joy in educational environments as well as neurologic disorders. The same study underlines that pastel and light colors like white and champagne should be preferred in educational environments.

When the studies, which are related to the ergonomic design of the classrooms, are considered, it can be seen that this issue is analyzed for a long time. Table 1 summarizes some of the mentioned studies in the literature and the suggested study according to their objectives and solution methodologies. The studies in the literature are given chronologically and this proposed study is given the undermost row in Table 1. Many studies only focus on the mismatches between the furniture dimensions and anthropometric measurements of the students. Additionally, their solution methodology only depends on the calculation of the anthropometric measurements. However, this study also determines the problems based on the environmental factors by analysis of the questionnaire and suggests some solutions by discussing the most critical problems in addition to determining the incompatibilities between the furniture dimensions and anthropometric measurements. It is aimed at the implemented methodology and discussions made in this study can be a contribution to the related literature by considered a comprehensive perspective for educational ergonomics.

Table 1. Summary of the literature and the proposed study

Study	Objective	Solution Methodology
Khoshabi et al. (2020)	Ranking and comparing classroom furniture depending on the mismatch between furniture dimensions and anthropometric measures of the university students.	Developing a multi-criteria decision-making approach, and using the mismatch equations and Simple Additive Weighting method to analyze mismatches.
Fidelis et al. (2020)	To survey the mismatches between the anthropometric measures of the students and furniture dimensions.	Computing the anthropometric measurements to define the mismatches.
Kahya (2018)	Investigating the suitability between the furniture dimensions and anthropometric measures of the students.	Calculating the anthropometric measurements to specify the incompatibilities.
Önder et al. (2013)	Making classroom design, which is proper for human physiology, by benefiting from the ergonomics and anthropometry.	Evaluating the anthropometric measurements to determine the mismatches and effects of environmental factors.
Yalçınkaya (2012)	Underlying the significance of ergonomic principles in the educational environments.	Explaining and discussing the methods of ergonomics principles in the educational environments by considering different environmental factors.
Castellucci et al. (2010)	Comparing the sizes of furniture and anthropometric characteristics of students to determine the possible mismatches.	Using a match criterion equation to evaluate the incompatibilities between furniture dimensions and anthropometric characteristics.
Jayaratne and Fernando (2009)	Determining the mismatches between the furniture sizes and anthropometric characteristics of students.	Estimating the anthropometric measurements to identify the mismatches.
Savanur (2007)	Identifying the incompatibilities between the furniture dimensions and anthropometric characteristics of students.	Determining the problems related to the furniture dimensions by questionnaire and calculating the anthropometric measurements to specify the incompatibilities.
Gouvali and Boudolos (2006)	Analyzing whether the dimensions of furniture match the anthropometric measures of the students.	Defining combinational equations for the acceptable dimensions of the furniture in terms of anthropometry and computing match percentages.
Grimmer and Milanese (2004)	Specifying the relations between reported spinal symptoms of students and the suitability of the furniture dimensions to the anthropometric measures.	Computing the odds ratios for reported spinal symptoms to examine the incompatibilities between the furniture dimensions and anthropometric measures.
Proposed Study	Specifying the environmental problems of the students for the classrooms and also, determining whether the dimensions of furniture match the anthropometric measures of the students.	Analyzing the questionnaire results according to the dissatisfaction score of each problem to prioritize the critical problems, discussing the most critical problems to suggest solutions, calculating the anthropometric measurements to determine the mismatches with furniture dimensions, and comparing the suggested furniture dimensions with the standard dimensions.

3. ANALYSIS of the QUESTIONNAIRE

The questionnaire that includes 28 questions is designed and implemented to the selected 219 students (65 female, 154 male) of the university. The chosen students have different grades and they are from different departments of the university. The questionnaire conducted for the study determines the satisfaction level of the students for each question. This determination is based on a satisfaction scale between 1 and 5. According to this scale, 1 and 5 mean lowest and highest satisfaction levels, respectively. The other values (2, 3, and 4) are for the intermediate satisfaction levels. The evaluation of the questionnaire is in Table 2. The numbers under each satisfaction level show the number of students, who grade the corresponding satisfaction level of the corresponding question.

Table 2. Evaluation of the questionnaire

No.	Question	1	2	3	4	5
1	Is the sitting position comfortable?	59	62	75	15	8
2	Is the sitting height well?	29	29	61	73	27
3	Are the chairs durable?	79	70	49	15	6
4	Is there enough space between the chair and desk?	33	30	60	58	38
5	Is there a problem with the noise of the furniture (creaking)?	50	43	60	60	6
6	Is the desk suitable for comfortable viewing?	34	40	57	61	27
7	Is the desk length appropriate?	36	36	71	41	35
8	Does the chair provide a comfortable position with your back?	80	66	28	6	39
9	Is the view angle of the board appropriate?	34	47	56	50	32
10	Is the distance to the board enough for you?	25	36	81	56	21
11	Is the number of seats sufficient?	45	37	46	55	36
12	Do you have enough space to put your objects on the chairs?	128	45	30	8	8
13	Is the desk comfortable to use a computer?	45	34	48	67	25
14	Are chairs suitable for listening to lessons?	73	63	44	25	14
15	Are the chairs suitable for using a computer?	155	29	16	9	10
16	Is the lighting good enough to see the writings on the board?	22	47	73	48	29
17	Are you satisfied with the color of the classes?	19	20	51	73	56
18	Do you prefer sunlight rather than bulb light?	35	25	63	54	42
19	Are you satisfied with the class heat in the winter?	71	39	34	44	31
20	Are you satisfied with the class heat in the summer?	54	47	58	29	31
21	Are you satisfied with the class heat in the spring?	31	22	60	55	51
22	Are you satisfied with the air conditioning?	74	43	58	29	15
23	Does the fly, insect etc. in the class affect the lesson?	58	34	40	42	45
24	Are you satisfied with the height of the board?	26	27	58	67	41
25	Are you satisfied with the width and position of the slide pitch?	25	30	62	66	36
26	Are you satisfied with the acoustics of the class (echo state)?	46	41	58	38	36
27	Are you satisfied with the position of the doors?	57	34	43	51	34
28	Are you satisfied with the back seats for listening to the lesson?	78	46	44	31	20

3.1. Dissatisfaction Score (DS)

It is important to determine the most dissatisfied questions. The purpose is to focus on the most critical problems of most of the students. To determine the questions that have minimum satisfaction level according to the questionnaire in Table 2, the dissatisfaction score (*DS*) is evaluated for each question by Equation 1.

$$DS_i = \Sigma_{i\in 1}\ \Sigma_{j\in J}\ X_{ij}\, c_j \qquad \forall i \in I \tag{1}$$

In Equation 1, the means the dissatisfaction score of question $i \in I$ (i = 1, 2..., 28). The means the dissatisfaction coefficient of the satisfaction level $j \in J$ (j = 1, 2, 3, 4, 5). The decision variable X_{ij} means the number of students, who prefer j^{th} satisfaction level of i^{th} question. For example, the value of X_{11} that means the number of students, whose grade satisfaction level 1 of question 1 is 59 according to Table 2. The c_j values are assigned according to the percentage values. The assigned values of c_1= 0,70, c_2 = 0,20, c_3 = 0,08, c_4 = 0,02, and c_5 = 0. It is assumed in this study that if the student gives 5 points to a certain question in the questionnaire, the student is completely satisfied. Therefore, c_5 is accepted as 0%. It is accepted in this study that the most important indicator of dissatisfaction is giving 1 point to the question in the questionnaire. In other words, it is very important to define the questions that they have mostly 1 satisfaction level. Therefore, a very high weight like 70% is assigned for the c_1. Similarly, the weight of c_2 is assigned as 20%. It means that 90% of *DS* of questions is depended on the 1 and 2 satisfaction levels in this study. Table 3 shows the *DS* values in descending order for each of the questions.

Table 3. DS and ranking values

DS_i	Question No.	DS_i	Question No.
115,76	15	43,68	11
101,16	12	43,48	13
73,52	3	38,9	7
71,56	8	38,68	9
67,94	28	37,58	6
67,72	14	35,62	18
65,62	22	35,06	4
61,1	19	32,44	2
60	1	32,3	10
52,42	20	32	21
51,44	23	31,6	16
51,16	27	29,78	25
49,6	5	29,58	24
45,8	26	22,84	17

The 10 questions that have the highest *DS* values are selected in Table 3. The selected problems are as the followings:

- Are the chairs suitable for using a computer? (Question 15)
- Do you have enough space to put your objects on the chairs? (Question 12)
- Are the chairs durable? (Question 3)
- Does the chair provide a comfortable position for your back? (Question 8)
- Are you satisfied with the back seats for listening to the lesson? (Question 28)
- Are chairs suitable for listening to lessons? (Question 14)
- Are you satisfied with the air conditioning? (Question 22)
- Are you satisfied with the class heat in the winter? (Question 19)
- Is the sitting position comfortable? (Question 1) Are you satisfied with the class heat in the summer? (Question 20)

It is seen from the *DS* results that most of the significant problems are related to the classroom chairs. In other words, it can be said that the discomfort of the chair is the biggest problem identified in the questionnaire results. The incompatibility between the anthropometric measures of the students and the

furniture dimensions of the classrooms is the main reason for this problem. It can cause musculoskeletal and postural dysfunctions for the students. Additionally, the learning performances of the students during the lesson can decrease.

The chairs in the classrooms of the university are single-seater tablet-armed chairs. Most of the students think that the tablet-armed chairs are not comfortable for their backs. The angle of the chair backs can cause this problem. If the angle of the chairbacks has an approximately straight angle, the students have to sit up straight during the lesson. Therefore, they may feel discomfort and lose their concentration. Similarly, if the chairbacks have an excessively wide-angle, the students can feel discomfort, especially when they want to use their notebooks for writing. The configurable chairbacks that depend on student pleasure can be an efficient solution for this problem. The quality of the chair back can also be a discomfort source for the student. If the fabric or material on the surface of the chairback is excessively solid, it can discomfort the students.

Most of the students also think that the tables on the armrests of the tablet-armed chairs are not suitable for using the computer. The main reason is the size of these tables is specially designed according to the writing comfort by considering the average sizes of the notebooks and books. However, the sizes of these tablet-armed chairs are not sufficient for the average laptop sizes.

There are special baskets to put objects under the tablet-armed chairs. Another significant problem is there is not enough space to put objects (knapsack, bag, book, notebook, laptop, calculator, etc.) of the students on the baskets. It is a very oppressive situation for the students, who put most of the objects on the tables of their tablet-armed chairs. Because their objects complicate writing on the notebooks and cause discomfort.

The durableness of the tablet-armed chairs is also important in terms of student satisfaction. According to the results, most of the students think that tablet-armed chairs are not durable. Sometimes, the students cannot find durable tablet-armed chairs in the classroom. Therefore, they have to sit on these broken tablet-armed chairs. Due to the broken legs or chairbacks of the tablet-armed chairs, the students cannot concentrate on the lesson completely and feel discomfort. It directly decreases the learning efficiency of the students during the lesson. This situation is also risky in terms of student health because the students can fall on the floor and they can become disabled.

Most of the students are also dissatisfied with the air conditioning of the classrooms. The students cannot feel relaxed and commodiously concentrate on the lesson because of the air conditioning problem. Especially, when the pandemic is considered these days, it is a very important problem for the students. Most of the students are also dissatisfied with the class heat in the summer and the winter. According to the study of Dönmez (2008), the suitable temperature range for the classroom environment is between 19.7 and 22.8 °C. It is important to protect the ideal temperature range for each season. Otherwise, the students can feel cold and get sick because of the cold temperature levels in the winter and they can swelter because of the hot temperature levels in the summer. Each of the situations decreases the learning performances of the students during the lesson. Therefore, the heating system of the university must be controlled accurately according to the changing seasons.

4. ANTHROPOMETRIC MEASUREMENTS

The anthropometric measurements should be taken into account to prevent the mismatch with the dimensions of the tablet-armed chairs. The calculation methods and the purposes of the anthropometric measurements used in this study are explained below. All of the measurements except the height are made while students are sitting with casuals. Table 4 shows the names of the anthropometric measurements, the calculation methods of the measurements, and the purposes of the measurements.

Table 4. The anthropometric measurements

Measurement	Method	Purpose
Shoulder Breadth (cm)	It is calculated by the horizontal distance between the maximum lateral protrusion of the left and right deltoid muscles.	It is used for the backrest width of the tablet-armed chairs.
Hip Breadth (cm)	It is calculated by the widest horizontal distance between the hips.	This value is used to determine the seat width of the tablet-armed chairs.
Shoulder Height (cm)	It is calculated by the vertical distance from the upper surface of the desk to the farthest shoulder protrusion of the scapula.	It is used to determine the backrest height of the tablet-armed chairs.
Elbow Height (cm)	It is calculated by the vertical distance of the lower part of the right elbow from the upper surface of the seat.	This value is used to determine the seat to desk height of the tablet-armed chairs.
Buttock- Popliteal Length (cm)	It is calculated by the distance between the posterior sides of the buttock and the knee.	It is used to determine the seat depth of the tablet-armed chairs.
Popliteal Height (cm)	It is the vertical distance of the back of the knee from the farthest point to the ground.	This data is used to determine the seat height of the tablet-armed chairs
Knee Height (cm)	It is calculated by the vertical distance of the middle point of the kneecap from the floor.	This value is used to determine the underneath desk height
Vertical Grip Reach (cm)	It is the longest distance that the arms can reach when they are extended in the forward direction.	It is used to determine the desk depth of the tablet-armed chairs.
Height (cm)	It is the vertical distance between the top of the head and the standing surface.	It is used to determine the seat height of the tablet-armed chairs.
Weight (kg)	It is the weight measurement made with casual clothes.	The desks must be able to withstand the maximum weight. Therefore, it is used to determine the durableness of the tablet-armed chairs.

In the study of Tunay et al. (2005), it is indicated that the population staying between 95 percent and 5 percent is intended to consider by design studies. Kahya (2018) indicates that 90 percent of users are considered in general researches on the subject of body measurements and 5 percent of the bottom and top are foreclosed from standard comprehension. In the same study, it is underlined that the standard dimensional specifications are dependent on anthropometric measurements of 95 percent of males and 5 percent of females in the product design that is used by both females and males. Tables 5 and 6 show the minimum, average, maximum, and percentage (5% and 95%) values of body measurements of female and male students, respectively.

Table 5. The necessary body measurements of female students

	Minimum	5%	Average	95%	Maximum
Shoulder Breadth (cm)	30	34,07	38,54	43,01	55
Hip Breadth (cm)	30	30,14	43,3	46,47	55
Shoulder Height (cm)	50	52,85	63,18	73,5	75
Elbow Height (cm)	19	19,49	28,04	36,59	37
Buttock- Popliteal Length (cm)	46	46,38	50,40	70,42	72
Popliteal Height (cm)	40	42,66	46,22	54,78	55
Knee Height (cm)	42	42,28	51,92	55,56	57
Vertical Grip Reach (cm)	68,9	69,28	75	80,78	82,4
Height (cm)	148	149,53	164,34	177,16	178
Weight (kg)	41	42,45	61,06	79,68	86

Table 6. The necessary body measurements of male students

	Minimum	5%	Average	95%	Maximum
Shoulder Breadth (cm)	40	40,2	43,44	49,96	50
Hip Breadth (cm)	36	36,27	47,32	48,37	55
Shoulder Height (cm)	60	60,8	70,54	75,29	83
Elbow Height (cm)	25	25,3	33,08	42,86	44
Buttock-Popliteal Length (cm)	51	53,36	65,58	65,8	67
Popliteal Height (cm)	43	46,02	55,26	68,5	69
Knee Height (cm)	49	49,08	58,54	62,01	68
Vertical Grip Reach (cm)	70	75,52	85,15	92	98
Height (cm)	164	164,63	175,76	190,89	193
Weight (kg)	60	60,63	82,9	106,18	107

5. RESULTS and DISCUSSIONS

The furniture dimensions according to the anthropometric measurements of students are explained below.

Seat Height: According to Castellucci et al. (2015), the seat height should be lower than the popliteal height because the students should be able to rest their feet on the posterior surface of the knee. The 5% percent of the popliteal height for the female students is 42,66 cm in this study. Therefore, this measurement is considered for seat height. Additionally, the 2,5 cm shoe correction value, which is considered in the study of Kahya (2018), is added to these values. Therefore, the obtained seat height in this study is 45,16 cm.

Seat Width: Oyewole et al. (2010) indicate that the hip breadth should be lower than the seat width to decrease the pressure on the buttocks and increase comfort and mobility capability. The 95 percent of the hip breadth of male students is 48,37 cm in this study. The dress correction is contained in this measurement because the measurement is made with clothing. In the study of Kahya (2018), 20 cm space is used for the double chairs. In this study, 10 cm space is added to hip breadth because the considered tablet-armed chairs are single-seater chairs. Therefore, the obtained seat width in this study is 58,37 cm.

Seat Depth: Gouvali and Boudolos (2006) state that the buttock popliteal length should be at least 5 cm longer than the seat depth. The 5 percent of the buttock popliteal length of the female students is 48,38 cm in this study. The 5 cm space is added to this measurement. Therefore, the obtained seat depth is 51,38 cm in this study.

Upper Edge of Backrest: In the study of Kahya (2018), the upper edge of the backrest is evaluated by excluding 10 cm from the 95 percent of shoulder height of male students. The same methodology is applied in this study. It means that 10 cm is excluded from 75,29 cm. Therefore, the obtained upper edge of the backrest is 65,29 cm in this study.

Height of Backrest: Because measuring the distance between lumber and subscapular height is difficult, the height of the backrest is assumed as 20 cm in this study.

Width of Backrest: The 95 percent of shoulder breadth of male students is 49,96 cm in this study. The 10 cm space is considered for single-seater chairs. Therefore, the obtained width of the backrest is 59,96 cm in this study.

Backrest Slope: The ideal backrest slope is suggested as 6 degrees for non-adjustable backrests. However, the adjustable backrest, which the slope can be changed based on student decision, is essentially suggested from this study.

Desk Height: The elbow height is the most significant criterion to measure desk height. The 5 percent of elbow height and popliteal height of female students in this study are 19,49 cm and 42,66 cm in this study. The 2,5 cm shoe correction value is added to the sum of these values. In addition to this, a 5 cm space is added because some studies suggest that the elbow height should be 5 cm lower than the desk (Kahya, 2018). Therefore, the obtained desk height is 69,65 cm.

Desk Width: The obtained width of the backrest is suggested for the desk width. Therefore, the obtained desk width in this study is 59,96 cm.

Desk Depth: In the study of Kahya (2018), the desk depth is calculated by adding 10 cm to the height of A4 paper (nearly 30 cm). Considering the questionnaire results of this study, most of the students complain about there is not enough space to put objects on the tablet-armed chairs. Considering this complaint, 15 cm space is added to 30 cm for student comfort. Therefore, the obtained desk depth in this study is 45 cm.

Underneath Desk Height: The seat to desk clearance must be large enough to permit comfortable movements of legs. Castellucci et al. (2015) underline that the seat to desk clearance is proper if the thigh thickness is lower than the seat to desk clearance. The 95 percent of knee height of male students (62,01 cm) is considered to evaluate the underneath desk height in this study. Also, the shoe correction (2,5 cm) is added to this value. Parcells et al. (1999) suggest that the knee height should be 2 cm lower than the desk clearance. Considering this suggestion, 2 cm of space is also being added. Therefore, the obtained underneath desk height is 66,51 in this study. The adjustable desks, which students can adjust the slope, the height, and the direction, are essentially suggested from this study.

The comparison between the suggested furniture dimensions and the dimensions of the Turkish Standards Institution (TSE) is made in some studies to determine the deviation from the standards (Kahya 2018; Tunay 2005). The comparison between the suggested furniture dimensions (cm) in this study and the dimensions (cm) of TSE standards (TSE, 2003) can be seen in Table 7. In Table 7, because the “Seat Width”, “Width of Backrest”, and “Desk Width” of the TSE Standard dimensions are for double seat and desk, half of these values are considered for the comparison. Half of the values are stated in brackets in Table 7.

Table 7. The comparison for furniture dimensions (cm)

Furniture Dimension	Suggested Dimensions	TSE Standard
Seat Height	45,16	45
Seat Width	58,37	110 (55)
Seat Depth	51,38	45
Upper Edge of Backrest	65,29	32
Height of Backrest	20	22
Width of Backrest	59,96	110 (55)
Slope	6°	6°
Desk Height	69,65	77
Desk Depth	45	40
Desk Width	59,96	110 (55)
Underneath Desk Height	66,51	57.5

According to the results that are mentioned in Table 7, while “Seat Height”, “Seat Width”, “Seat Depth”, “Upper Edge of Backrest”, “Width of Backrest”, “Desk Depth”, “Desk width”, and “Underneath Desk Height” have higher-valued dimensions; “Heigth of Backrest” and “Desk Height” have lower-valued dimensions and only “Slope” has equal-valued dimensions when compared to the TSE Standard dimensions. Among these values, especially, “Upper Edge of Backrest”, “Desk Height” and “Underneath Desk Height” have

higher deviations from the TSE Standard dimensions, thus, they seem to affect the comfort of the students for the educational conditions.

6. CONCLUSION

In this study, an experimental study is implemented in order to find appropriate classroom furniture dimensions by making use of real data and a questionnaire in a university in Ankara. For efficient results, the questionnaire helped to find the most complained problems by the students, about the classroom furniture and environment. The dissatisfaction values are calculated by the developed methodology. For the dissatisfaction, the satisfaction levels 1 and 2 are assigned high percentages, 70% and 20%, respectively.

According to the results, most of the students complain about the problems related to the tablet-armed chairs. To minimize the incompatibilities between the anthropometric measures of the students and the furniture dimensions of the classrooms, the required measurements are calculated. According to the measurements observed from the students, the suggested furniture dimensions are obtained. Then, these suggested dimensions are compared with the dimensions of the TSE standards to see the deviation level from the standards. It is detected that eight of the results have higher values, two of the results have lower values than the standards and finally, only one result has the same value as the standard values. This indicates that the standard values determined by the TSE might be modified continuously since the body measurements of the students change as time passes.

The study is limited to only one university and for a limited sample size. Thus, for more effective and sensitive results, it would be better to use a larger sample size for the students who are evaluated. As a contribution, considering theoretical and experimental studies made in the literature, this study fosters using real data and use of end-user satisfaction by using a questionnaire in a university. As a result of the study, standard dimensions are also compared and new values are suggested. By diminishing the dissatisfaction of the students, the productivity of the education increases in the university since the students' comfort increases. As a future study, by combining this study with the ergonomy of classrooms, a contemporary classroom design can be obtained that may affect positively the productivity of higher education with larger sample size.

REFERENCES

ALTAN, İ. (1989), **Aydınlatma ve Aydınlatmada Gölge Etkeni**, Çukurova Üniversitesi Milli Prodüktivite Merkezi 2. Ulusal Ergonomi Kongresi, Adana, 412-421.

CASTELLUCCI, H. I., AREZES, P. M. and VIVIANI, C. A. (2010), **Mismatch between Classroom Furniture and Anthropometric Measures in Chilean Schools**, Applied Ergonomics, 41, 563-568.

CASTELLUCCI, H. I., AREZES, P .M. and MOLENBROEK, J. F. M. (2015), **Equations for Defining the Mismatch between Students and School Furniture: A Systematic Review,** Applied Ergonomics, 48, 117-126.

DEMİRKAN, H. (1995), **Eğitim Kalitesine Uygun Öğrenme Mekanları Tasarımı**, 5. Ergonomi Kongresi, İstanbul, 413-420.

DÖNMEZ, B. (2008), **Okul ve Sınıf Ergonomisi ya da İnsanı Öncelemek**, Eğitime Bakış Eğitim-Öğretim ve Bilim Araştırma Dergisi, 4 (11), 10-14.

FIDELIS, O. P., ADELAKUN, S. A. and OGUNLADE, B. (2020), **Ergonomic Assessment and Health Implications of Classroom Furniture Designs in Secondary Schools: A Case Study**, Theoretical Issues in Ergonomics Science, 1-14.

FIĞLALI, N. (2009), **Ergonomi'nin Dünü Bugünü Yarını**, V. Endüstri Mühendisliği Bahar Konferansları-Ergonomi, Endüstri İşletme Mühendisliği Meslek Dalı Ana Komisyonu Bülteni, Türkiye, 19-21.

GOUVALI, M. K. and BOUDOLOS, K. (2006), **Match between School Furniture Dimensions and Children's Anthropometry**, Applied Ergonomics, 37, 765-773.

GRIMMER, K. and WILLIAMS, M. (2000), **Gender-Age Environmental Associates of Adolescent Low Back Pain**, Applied Ergonomics, 31, 343-360.

GRIMMER, K. and MILANESE, S. (2004), **School Furniture and the User Population: An Anthropometric Perspective**, Ergonomics, 47, 416-426.

HİRA, D. S. (1980), **An Ergonomic Appraisal of Educational Desks**, Ergonomics, 23, 213-221.

JAYARATNE, I. L. K. and FERNANDO, D. N. (2009), **Ergonomics Related to Seating Arrangements in the Classroom: Worst in South East Asia? The Situation in Sri Lankan School Children,** Work, 34, 409-420.

KAHYA, E. (2018), **Evaluation of the Classroom Furniture for University Students**, The Journal of Engineering and Architecture Faculty of Eskisehir Osmangazi University, 26 (1), 20-29.

KHOSHABI P., NEJATI, E., AHMADI, S. F., CHEGINI, A., MAKUI, A. and GHOUSI, R. (2020), **Developing a Multi-Criteria Decision Making Approach to Compare Types of Classroom Furniture Considering Mismatches for Anthropometric Measures of University Students**, PLoS ONE, 15 (9), 1-25.

OYEWOLE, S. A., HAIGHT, J. M. and FREIVALDS, A. (2010), **The Ergonomic Design of Classroom Furniture/Computer Work Station for First Graders in the Elementary School,** International Journal of Applied Ergonomics, 40, 437-447.

ÖNDER, H., H., GÜL, M. and ERGÜLDÜRENLER, G. (2013), **Eğitim Ortamında Ergonomi Kullanılması ve Örnek İdeal Sınıf Çalışması**, Süleyman Demirel Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, Büro Yönetimi Özel Sayısı (1), 41-55.

PANAGIOTOPOULOU, G., CHRISTOULAS, K., PAPANICKOLAOU, A. and MANDROUKAS, K. (2004), **Classroom Furniture Dimensions and Anthropometric Measures in Primary School**, Applied Ergonomics, 35, 121-128.

PARCELLS, C., STOMMEL, M. and HUBBARD, R. P. (1999), **Mismatch of Classroom Furniture and Student Body Dimensions: Empirical Findings and Health Implications**, Journal of Adolescent Health, 24, 265-273.

ROWANI, M. P. and WRIGHT, P. C. (1994), **Ergonomics is Good for Business**, Work Study, 43 (8), 7-12.

SAVANUR, C. S., ALTEKAR, C. R. and DE, A. (2007), **Lack of Conformity between Indian Classroom Furniture and Student Dimensions: Proposed Future Seat/Table Dimensions**, Ergonomics, 50, 1612–1625.

SLUCHAK, T. J. (1992), **Ergonomics: Origins, Focus and Implementation Considerations**, AAOHN Journal, 40 (3), 105-11.

SMITH, T. J. (2012), **Integrating Community Ergonomics with Educational Ergonomics-Designing Community Systems to Support Classroom Learning,** Work, 41, 3676-3684.

TSE, (2003), **Mobilya-Eğitim Kurumlarında Kullanılan Sandalyeler ve Masalar, Bölüm I: Fonksiyonel Boyutlar,** Türk Standardı, TS 3585 ENV 1729-1, Ankara.

TUNAY, M., MELEMEZ, K. and DİZDAR, E. N. (2005), **Yüksek Öğrenimde Kullanılan Okul Sıra ve Masalarının Antropometrik Tasarımı (Bartın Orman Fakültesi Örneği)**, Teknoloji, 8 (1), 93-100.

WANG, J., THORNTON, J. C., KOLESNIK, S. and PIERSON, R. N. (2000), **Anthropometry in Body Composition: An Overview,** Annals of the New York Academy of Sciences, 904 (1), 317-326.

YALÇINKAYA, B. (2012), **Eğitim Ortamında Başarının Gizli Etkeni: Ergonomi**, e-Journal of New World Sciences Academy NWSA-Education Sciences, 1C0543, 7 (2), 785-797.