

# An Ergonomic Student Chair Design and Engineering for Classroom Environment

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**Abstract**—Classroom chair is considered as an important element for students to improve comfort and concentration in study environment. An ergonomic chair design and engineering is therefore considered very important for its usability and comfort point of views for the students. An ergonomic chair ensures better comfort and confidence for the students in a classroom environment. This research study is proposed an innovative ergonomic chair design and engineering with the objective to satisfy all the basic needs of the students in the classroom environment. In order to design and engineering this proposed chair, relevant data was collected from the prospective students through face-to-face interview, and both online and off-line questionnaires surveys. The proposed chair was tested and validated and fine-tuned based on the students' feedback after using it exclusively. This research study is concluded with study limitations and future research directions.

**Index Terms**—ergonomic chair, classroom environment, anthropometric data of students, sitting comfort and safety.

## I. INTRODUCTION

Generic ergonomics chair design and engineering is not a new concept but various researchers have been conducted several valuable researches on this very important issue [1, 2, 3, 4]. However, there are limited researches have been conducted so far on the chair design and engineering considering the absolute needs and expectations from the students in the classroom environment. In addition to aesthetics point of views, an ergonomic chair should have additional features related to the ease of use, ease of maintenance, seating comfort, durability, etc., [5]. An ergonomic chair used in the classroom environment should contributes towards the students' attention and motivation during the lecturing period. Along with the attention and motivation issues, a poor chair design is also responsible for the problems associated with the students' body parts such as ligaments, joints and the spine [6, 7, 8]. The basic functionality of an ergonomic classroom chair should fulfill students' expectations such as relaxation, comfort, enough space for writing, space for school bag, etc. Considering all such functionalities, an ergonomic chair needs to be designed in order to achieve various ergonomics qualities or features.

In any chair design, there needs to aesthetics feature in one hand and features related to comfort and relaxation are on the other hand. A chair user could distinguish between the parameters that are related to comfort and relaxation easily but he/she often finds it difficult to distinguish between the ergonomics features of the chair. For instance, many ergonomics features are supposed to relief discomfort in sitting are indistinguishable because they cannot be perceived [6]. In ergonomic chair design, the formulization of qualitative criteria with quantitative criteria can leads to various advantages such as reducing developmental lead-time and cost, increasing users comfort and reliability, etc. [9].

This research study aimed to determining the relationship between the anthropometric dimensions of university students with the dimensions of the classroom chairs. The objective of this study is to design and develop an innovative ergonomics chair to bring both qualitative and quantitative design criteria, which are suitable to the classroom environment. This work included a sample of 472 students (both male and female) from Sultan Qaboos University (SQU), Muscat, Oman. Descriptive statistics were analyzed for all predefined designs and anthropometrics criterions of the proposed chair. The study results shown that the current dimensions of the existing chairs in the classroom are not suitable to a large number of students at SQU. Currently, available classroom chairs at SQU are provided in only one size and do not fit all kind of users' needs properly. Within the scope of this research study, various design criteria of a chair are viewed from the users' perspectives and improved design solutions are iteratively proposed through the cooperative efforts of the users and computer simulations.

The rest of the paper is organized as follows: Section II presents a brief review of the existing literature on furniture design and development, especially within the classroom environment, while in Section III, detail research methodology is highlighted. In Section IV, all the students' both functional and technical requirements are elaborated. Proposed ergonomics chair design and engineering for the classroom environment is elaborated with respect to concept generation, concept screening and scoring in Section V. Required industrial design and engineering of the proposed ergonomics chair is stated in Section VI with necessary dimensions and 3D views. In

Section VII, essential testing and validation of the students chair is explained. This paper is concluded with future research directions in Section VIII.

## II. LITERATURE REVIEW

There is a common problem in the classroom environment not to have ergonomically designed chair, which results in abnormal postures. This causes increased physical strain, generates muscular back, neck and head pains, loss of concentration and restlessness in an attempt to find a better position [10, 11, 12]. A number of studies shown that most of the physical problems in the classroom environment are due to the mismatch between anthropometric dimensions of the students at different ages and dimensions and also closely related to incorrect sitting posture [13, 14, 15, 17].

Existing student's chair within classroom environment does not fully support an up-to-date need of contemporary academic regulations. Several researchers have tried to initiate appropriate student chair design following the standard anthropometric dimensions [2, 18, 19]. However, their efforts are mostly devoted towards the theoretical level and mainly in two-dimensional and not three-dimensional geometric space. In general, existing students' chairs are designed mostly in a traditional way and are not much designed considering the ergonomics principles [20]. One of the most important needs for classroom chair design is to consider the relationship between the students' anthropometry and chair's functional dimensions [21, 22, 23].

Usually, the classroom chairs and desks that are designed and developed by the furniture manufacturers are not suitable for individual students but they are manufactured considering average students anthropometric dimensions. These types of chairs are mainly non-adjustable and cannot fulfil the generic requirements of the students due to their different anthropometric dimensions [24, 25, 26, 27]. The manufacturers consider developing such generic chair with the objective to reduce developmental cost and inventory level [34]. Five major school furniture manufacturers in the United States were interviewed about how they rely on for their furniture design. The response were that they did not rely on any field surveys but mainly collecting necessary design specifications from American Furniture Manufacturers Association and the National Standards Board [28].

Although, manufacturing and inventory costs are important concerns in designing classroom chair, but at the same time, it is also important to consider anthropometric data and ergonomics during design phase [16, 17, 27]. Substantial researches in the area of school chair and desk have been done in the Scandinavian countries including Denmark and Sweden and the trend is also spreading in Germany, France and Switzerland [29, 30]. The starting point to design and develop an ergonomic student's chair is to investigate how the dimensions and styles of the chairs and desks are actually used in the classroom environment to reflect the body

dimensions and the functional requirements of today's vast students' population [31, 32].

## III. RESEARCH METHODOLOGY

This research is conducted within the campus of Sultan Qaboos University (SQU), Muscat, Oman during the period from February to May 2016. In this research study, in total 472 SQU students (from both male and female) were taken as the sample size within the age between 20 to 25 years. They were asked various questions related to classroom chairs as they are using during lecture time on the weekdays. In general, there were several complains and discomforts to using the current classroom chairs due the poor functionalities. To overcome such complaints from the students, this study proposed to design an ergonomic chair that is suitable for classroom environment with added comfort.

The idea to design and develop an ergonomic classroom chair came after collecting requirements from the students through several face-to-face meeting, workshops, distribution of hardcopy questionnaires physically and online questionnaires through emails. The objective of this survey was to examine possible mismatch between the individual body dimensions of students and the classroom chairs as they are using currently.

### A. Data Collection

Various anthropometric measurements were gathered during the survey. The data includes the height and weight of the students. These two criteria's were used to specify the right dimension of the chair. Collected anthropometric data from the students were then used to set the ratios of some important body parameters such as knee height, buttock knee length, body width, back length, chest depth, under arm to elbow length, and index figure to elbow. The data associated with students' height were analyzed using Excel and Minitab software.

Fig. 1 displays the students' heights with 95% percentile. From Fig. 1, it is seen that the lower margin is 128 cm, upper margin is 194 cm and the mean is 161 cm.

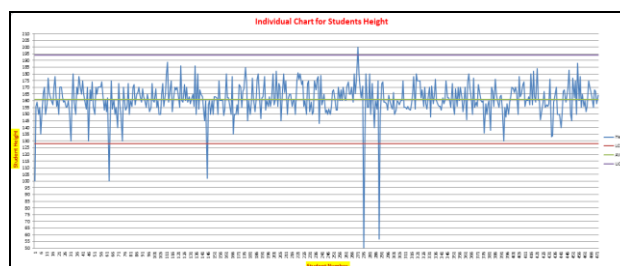


Figure 1. Display of 472 students height with 95% percentile

Table I highlights different measurements as necessary to design the ergonomics chair. Brief explanation of each of the measurements is also presented in Table I. All these measurement data were collected from the students' survey.

TABLE I. RELATIONSHIP BETWEEN THE CHAIR'S DIMENSIONS AND THE BODY MEASUREMENTS

Body measurements	Relation
Knee height	Use to find the height of the chair
Buttock knee length	Use to find the length of the seat
Body width	Use to find the width of the seat
Back length	Use to find the height of the seat
Chest depth	Use to find the distance between the table area and the seat
Under arm to elbow length	Use to find the height of the table area and if the table needs to move vertically.
Index finger to elbow	Use to find if the table area needs to move horizontally.

The necessary anthropometry data as collected from students' survey were populated in Table II. From Table II, it is seen that all required seven body measurement data is collected from the survey and used to design the proposed ergonomics chair. Seven body measurements as outlined in Table II were found by following two sequential steps. Firstly, average of the seven measurements as directly collected for sample from students were taken. Secondly, proportionality constant of body segments theory was used to get all the seven measurements. The proportionality constant of seven body measurements were then multiplied by the average height of the students and the outcomes are seen in Table II.

TABLE II. SEVEN BODY SEGMENTS RATIO OF SURVEYED STUDENTS

	Heights	Knee Height	Buttock Knee length	Body Width	Back Length	Chest Depth	Underarm to Elbow Length	Index Finger to Elbow
% Prediction to Statue Height	1.00	0.31	0.245	0.259	0.235	0.14	0.17	0.23
Average Height (168 cm) * Prediction to Statue Height	168 cm	52.08 cm	41.16 cm	43.51 cm	39.48 cm	23.52 cm	28.56 cm	38.64 cm

The seven body measurements as presented in Table II are used to design the chair with necessary dimensions. Various required dimensions and their corresponding names are shown in Fig. 2 and Table III respectively.



Figure 2. Display of different dimensions of the proposed student's chair

TABLE III. DIFFERENT DIMENSIONS OF THE PROPOSED STUDENT'S CHAIR

Measurement number	Name of the measurement	Value of the measurement (cm)
1	Height of the chair	52
2	Length of the seat	41
3	Width of the seat	44
4	Height of the back seat	48
5	Distance between the desktop and the back seat	40
6	Height of the desktop	32
7	Horizontal movements of the desktop	24

IV. REQUIREMENTS OF THE STUDENT'S CHAIR

The overall requirements (students' requirements, functional requirements and technical requirements) of the proposed chair, importance of each requirements and technical versus functional requirement metrics are elaborated in this section. Each of the sub-sections is stated accordingly.

A. Students (Customers) Needs

After necessary sorting, the students' requirements as collected from both the online and face-to-face survey nine critical requirements were identified as presented in Table 4. All these requirements are also transferred to functional requirements as needed to design and engineer the chair are highlighted within Table IV.

TABLE IV. STUDENTS REQUIREMENTS AND FUNCTIONAL REQUIREMENTS OF THE CHAIR

No .	Students requirements (customers)	Functional requirements
1	It would be good if there are holes in the chair, especially at the sitting place to prevent heat that causes sweating, irritating, etc.	The chair is provided with holes at the sitting place.
2	It is expected that the chair should have arms to support hands, and elbows while writing.	The chair is provided with arms to support for hands, and elbows.
3	It is desirable that the chair should have space to keep bags/books, especially during lecture hours.	The chair is provided with space for bags/books.
4	It is expected that the chair will be designed and engineered with variety of colors.	The chair is designed and engineered with multiple colors.
5	It is recommended that the chair height is adjustable to accommodate different sizes of students.	The chair is provided with adjustable height to fit for different sizes of students.
6	The chair must have enough space on the desktop to put book while writing comfortably during the lecture time.	The chair is provided with enough space for the desktop to put book, while writing.
7	It is expected that the chair should have feet rests to provide necessary comfort to the students while seating.	The chair is provided with feet rest.
8	The size of the chair should be suitable for all types of students with different sizes and weights.	The chair is designed with a suitable size to fit for all types of students.
	The chair should provide soft materials on the seating place for comfortable seating during lecture time.	The chair is provided with cushion material on the seating place for additional comfort while seated.

**B. Arranging the Importance of the Needs**

Table V presents the importance of the functional requirements as received from the students' survey. This ranking was done from the scale from 1 to 5 (1 is the highest and 5 is the lowest).

TABLE V. IMPORTANCE OF FUNCTIONAL REQUIREMENTS

No.	Functional requirements	Importance
1	The chair is provided with holes at the sitting place.	4
2	The chair is provided with arms to support for hands, and elbows.	2
3	The chair is provided with space for bags/books.	3
4	The chair is designed and engineered with multiple colors.	4
5	The chair is provided with adjustable height to fit for different sizes of students.	5
6	The chair is provided with enough space for the desktop to put book, while writing.	3
7	The chair is provided with feet rest.	5
8	The chair is designed with a suitable size to fit for all types of students.	5
9	The chair is provided with cushion material on the seating place for additional comfort while seated.	1

**C. Technical Requirements Versus Functional Requirements Metrics**

Table VI highlights nine technical requirements versus seven functional requirements metrics of the proposed chair and their interdependencies with each other.

TABLE VI. TECHNICAL REQUIREMENTS VERSUS FUNCTIONAL REQUIREMENTS METRICS OF THE CHAIR

Technical requirements	Functional requirements	The chair is provided with holes at the seating place.	The chair is provided with arms to support for hands, and elbows.	The chair is provided with space for bags/books.	The chair is provided with adjustable height to fit for different sizes of students.	The chair is provided with enough space for the desktop to put book, while writing.	The chair is provided with feet rest.	The chair is designed with a suitable size to fit for all types of students.	The chair is provided with cushion material on the seating place for additional comfort while seated..
The chair has holes		X							
The chair has hand support			X						
The chair can hold many books				X					
The chair is attractive with different colors					X				
The chair is adjustable to fit different length						X			
The chair provides enough space for books and for writing				X			X		
The chair can hold the feet while seating								X	
The chair is designed with a suitable size for all kind of students					X				X
The chair is covered with cushion at the seating place									X

**V. ERGONOMIC STUDENT CHAIR DESIGN AND ENGINEERING**

**A. Concept Generation**

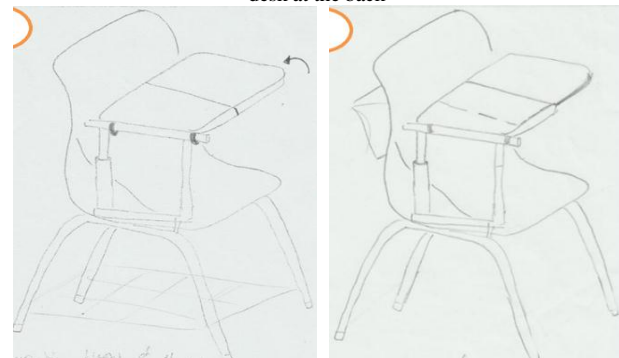
The concept of the proposed chair is generated after analyzing all the requirements such as students' requirements, functional requirements and technical

requirements. From the students requirements it was revealed that major problems of the existing classroom chair are related to the seating comfort, bag/book holder, size of the writing desk (desktop), adjustable desktop, etc. Considering such major requirements, the proposed chair should have several state-of-the-art functionalities such as desktop should be proper in size for comfortable writing, height of the desk should be adjustable, there should have a bag/book holder and comfortable seat cushion. From the study, it is also noticed that the students are complaining about sweating and irritating while seated on the chair, which is considered during the conceptual design of the ergonomic chair.

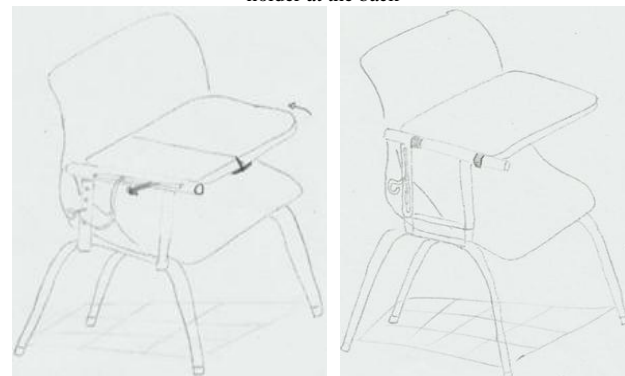
In this stage, 6 different chair concepts were generated based on students' requirements. Each conceptual chair design has its own design features and functionalities. All six conceptual chair designs are presented in Fig. 3 with their brief descriptions.



(a) Foldable desktop with book holder (b) Bag/book holder at lower desk at the back



(c) Foldable but fixed height desktop (d) Fixed height desktop and book holder at the back



(e) Adjustable desktop with threaded nail (f) Non-foldable desktop with adjustable height by spring

Figure 3. Six conceptual chair design with accompanied design and functional features

**B. Concept Selection**

After generating all six conceptual chair designs the next available step was to select an appropriate chair design t in order to fabricate it. In this concept selection process two steps such as concept screening and concept scoring were advocated which are explained below.

**B.1 Concept screening to select, design and develop an ergonomic chair**

The concept screening is a method, which is used to narrow down the number of concepts quickly and to improve the concepts qualities. This process was done with the objective to evaluate and reduce the number of generated concepts that were taken into account to satisfy students’ needs. This step was completed by comparing relative advantages and disadvantages of each of the generated concepts and to select one or more concept at the end.

In concept screening process, one of the conceptual designs is considered as a reference concept, which is used as the base to compare other available concepts. In this process, conceptual design named with ‘Fixed height desktop and book holder at the back’ [Fig. 3 (d)] was considered as the reference conceptual design. If any of the conceptual design of the chair is better than the reference conceptual design, it is marked by plus (+) sign. On the other hand, negative (-) sign is used for the worst design than the reference design and zero (0) sign for the same design as of reference concept. Net score was calculated by summing up the positive and negative values. The concepts were ranked based on the total scores from highest to the lowest.

This concept screening process was considered as the way out to reduce the number of selected concepts and to select the best one finally. Several selection criterions such as ergonomics and safety, ease of use, ease of manufacture, durability, aesthetics, etc., (Table VII) were used to rank the concepts and to choose the best one. Both the concept screening and scoring process follow a six step process, which leads the design team through the concept selection activity. The six steps are given as below:

- (1) to prepare the selection matrix
- (2) to rate the concepts based on selection criterions
- (3) to rank the concepts based on summed scores
- (4) to combine and improve the concepts
- (5) to select one or more concepts
- (6) to reflect on the results and the process

The six available concepts with their brief explanations are as follows:

Conceptual design ‘a’: Foldable desktop with book holder at the back

Conceptual design ‘b’: Adjustable desktop and bag/book holder at lower desk

Conceptual design ‘c’: Foldable but fixed height desktop

Conceptual design ‘d’: Fixed height desktop and book holder at the back

Conceptual design ‘e’: Adjustable desktop with threaded nail and foldable desktop

Conceptual design ‘f’: Non-foldable desktop with adjustable height by spring

TABLE VII. DISPLAY OF CONCEPT SCREENING MATRIX

Selection Criteria	Conceptual design					
	a	b	c	d (reference)	e	f
Ergonomics and safety	+	+	0	0	-	+
Ease of use	0	+	+	0	-	-
Ease of manufacture	+	0	+	0	0	+
Durability	0	-	+	0	0	+
Aesthetic	+	-	-	0	-	-
Reliability	0	-	-	0	+	+
Maintainability	-	+	+	0	-	+
Social appeal	+	-	0	0	-	+
Environmental soundness	0	+	+	0	-	-
Economic value	+	-	+	0	-	+
Utility and function	-	0	0	0	+	+
Life cycle cost	0	-	+	0	+	-
Availability	+	+	-	0	-	+
Sum of ‘+’s	6	5	7	0	3	9
Sum of ‘0’s	5	2	3	13	2	0
Sum of ‘-’s	3	6	3	0	8	4
Net score	3	-1	4	0	-5	5
Rank	3	5	2	4	6	1
Continue?	Revise	No	Yes		No	Yes

From Table VII, it is noticed that conceptual design ‘a’, ‘c’ and ‘f’ are initially selected due to their better ranks than other available concepts, which was based on their net scores as calculated by the difference between plus and minus indicators of the selection criterions.

**B.2 Concept scoring to select, design and develop an ergonomic chair**

The objective of concept scoring is to select the best conceptual design of the proposed ergonomic chair among the three concepts (‘a’, ‘c’ and ‘f’) as preliminary selected through concept screening process. In this process, all the selection criterions are given with specific weights in percentage, which are dependent by consensus or based on students requirements. These weights are distributed among the selection criterions and sum of all weights should be 100 as displayed in Table VIII.

After distributing the weights among 13 criterions, the next available step is to rate the concepts. The rates are categorized in relative comparison with the reference conceptual design. The rates of the concepts are recommended to give a scale of 1 to 5, which are defined and categorized as follows:

<u>Relative performance</u>	<u>Rating</u>
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Each of the weighted score for the selection criteria is achieved by multiplying the rating with specific weight,

which is finally summed up to get the total weighted score. The outcomes from the concept scoring are presented in Table VIII. From Table VIII, it is noticed that the concept ‘f’ is selected as the best one and continue for the design and development.

TABLE VIII. DISPLAY OF CONCEPT SCORING MATRIX

Selection criteria	Weight	Concept					
		a (reference)		c		f	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ergonomics & Safety	10%	3	0.30	2	0.20	4	0.40
Ease of Use	10%	3	0.30	2	0.20	4	0.40
Ease of Manufacture	10%	3	0.30	3	0.30	5	0.50
Durability	10%	3	0.30	4	0.40	4	0.40
Aesthetic	5%	2	0.10	3	0.15	3	0.15
Reliability	7%	2	0.14	2	0.14	3	0.21
Maintainability	7%	4	0.28	3	0.21	4	0.28
Social appeal	6%	2	0.12	3	0.18	3	0.18
Environmental soundness	8%	4	0.32	2	0.16	3	0.24
Economic value	9%	3	0.27	2	0.18	5	0.45
Utility and function	6%	2	0.12	3	0.18	3	0.18
Life cycle cost	7%	3	0.21	2	0.14	3	0.21
Availability	5%	3	0.15	2	0.10	4	0.20
Net score Rank		2.91 Second		2.54 Third		3.59 First	
Continue?		No		No		Develop	

VI. INDUSTRIAL DESIGN

In any industrial design, the designers have to keep in mind that the developed products should fulfil the customers’ expectations. In general, it is also expected that the developed product should satisfy the predefined specifications and functionalities to support both the users and manufacturers. In order to design and develop the selected students’ chair, two design aspects were considered such as ergonomics and aesthetics.

A. Ergonomics

Ergonomics is a way to work smarter – not harder by designing tools, equipment, workstations and tasks to fit the job to the worker – not the worker to the job. That is why various ergonomics criteria are considered as the most important criteria during product design phase. In the proposed chair design several ergonomics issues such

as ease of use, ease of writing on the desk, interaction between the chair and the user, etc., were considered. Various ergonomics issues with respect to students’ needs of the proposed chair are highlighted in Table IX with necessary explanation.

TABLE IX. THE IMPORTANCE OF ERGONOMICS ISSUE IN THE PROPOSED CHAIR DESIGN

Students needs	Level of Importance Low medium high	Explanation of rating
Ease of use		Good for sitting in a comfort posture since the chair will be used for several hours in a day.
Ease of writing on the desk		It is important because the users need the chair to be appropriate in ensuring the best posture for writing on the desk.
Interaction between the chair and the user		There are important interactions between the user and the chair. For example, controlling the desk by controlling the height through attached nail.
Safety		There needs to consider safety issues for the user and the used accessories.

B. Aesthetics

Another important criterion in any product design is to consider the looking of the product itself, which is known as aesthetics of the product. This product’s aesthetic contributes substantially to satisfy the customer needs. In the proposed chair design, several aesthetics issues such as social appeal, color, dimension, cushion material, etc., were also considered into account. Various aesthetic issues with respect to students’ needs of the proposed chair are highlighted in Table X with brief explanation.

TABLE X. THE IMPORTANCE OF AESTHETICS ISSUE IN THE PROPOSED CHAIR DESIGN

Students needs	Level of Importance		Explanation of rating
	Low	medium high	
Social appeal			There needs to consider social aspects for the users and to be attractive
Color			The users would be able to choose different colors to become attractive to use
Cushion material			Good material to offer a comfort seating for the users during long hours.

C. Product Architecture

The product architecture can be defined as a scheme, where functional elements of the product are arranged into physical chunks and by which the chunks interact. This architecture is linked to system-level design, which has profound implications for how the product is designed, manufactured, sold, used and repair, etc. The product architecture phase starts to emerge during the

conceptual phase of the product development. In the proposed chair design two chunks such as physical and functional were identified and presented as follows:

Physical chunks:

- 1) Seat with back support
- 2) Desktop for writing
- 3) Main base to hold the desktop
- 4) Lower basket to hold the bag\book
- 5) Four legs

Functional chunks:

- 1) Mechanism of sliding the desktop
- 2) Adjustability of the desktop's height

#### D. Material Selection

Considering the overall mechanical property, cost and the availability, two materials were selected for the proposed ergonomics chair design and engineering, which were carbon steel and PVC (polyvinyl chloride) plastic. Both the materials were selected due to their important properties as corrosion resistance and light weight with higher strength. The carbon steel has some properties that enable it to withstand a lot of mechanical defects such as corrosion, brittleness, water penetration, surface roughness, etc. It has a high strength and elastic modulus, which mean it can withstand a high load without rapid failure. The carbon steel was used to make the metallic parts of the chair. On the other hand, the PVC plastic is comparatively cheap material and widely used to make the plastic parts. The PVC plastic was used to make the plastic parts of the ergonomics chair.

#### E. Product Design

After the best concept was selected the next available step was to design each parts of the chair by using solid works software. This process eases the necessary engineering/manufacturing of the chair according to the predefined specifications. Each parts of the chair are displayed with its required dimensions and explanations.

From literature review, it is identified that the best ergonomics and healthy position while seating on a chair is  $135^{\circ}$  and not the  $70^{\circ}$  or  $90^{\circ}$  positions [33, 35]. However, as the proposed ergonomics chair is designed for the classroom environment, it is not convenient to lie down during the lecturing hours and due to such reason the chair is designed at  $120^{\circ}$  as the maximum angle. Different three-dimensional views of the proposed chair are displayed in Fig. 4.



Figure 4. Different 3D views of the proposed student's chair as drawn by solid works software

The complete chair assembly with necessary dimensions is displayed in Fig. 5. In order to minimize the common back pain problem, the chair is designed with 'S' shaped. All the required dimensions of the chair are given based on considering the ergonomics aspects as collected from students' survey.

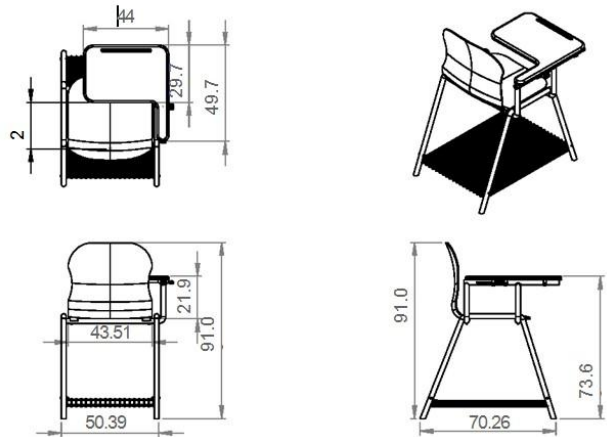


Figure 5. Display of proposed student's chair design with necessary dimensions

#### VII. PRODUCT TESTING AND VALIDATION

In order to perform the required testing and validation of the developed chair the students were interviewed to observe whether their needs have been adequately met or not. Several steps were accomplished to test and validate the concept as stated below:

- 1) Define the purpose of the test
  - There are alternative chair concepts should be pursued for the students
  - Improve the selected concept within a level that will satisfy most of students needs
  - Specify the number of units to be sold in the market
  - Decide whether to continue on developing the concept or not
- 2) Choose a survey population
  - Students at higher schools
  - Students at the colleges
  - Students' from the university
  - And other users who might use this product
- 3) Choose a survey format
  - Through workshop
  - Face-to-face interview
  - Through e-mails
- 4) Communicate the concept
  - Through sketch of the concept by using CAD prototype
  - Through sketch of the concept by using solid works software
  - Using working prototype of the chair concept
  - Verbal description of the product (chair)

Six questions were prepared and distributed during the testing and validation survey, which were as follows:

- (1) Do you like our new product (chair) design?
- (2) What do you like most of our newly developed product (chair)?
- (3) What do you like least of our newly developed product (chair)?
- (4) What do you think about the product (chair) color?
- (5) What are your biggest concerns about buying the new product (chair)?
- (6) Are you willing to buy the new product (chair) with more than 25.00 O.R. (Omani Real, equivalent to 40.00 €)?

In order to validate the proposed chair design, all six questions were analyzed after collecting students' feedbacks. For simplicity, three (questions 1, 4, and 6) out of six questions were demonstrated here as samples. From the feedbacks it is noticed that most of the students' feedbacks were very much interesting, useful and encouraging. The students' feedbacks from the first question are displayed in Fig. 6. From Fig. 6, it is noticed that 50% of the students strongly like the product (chair), while more than 37% like and 12.5% did not like it.

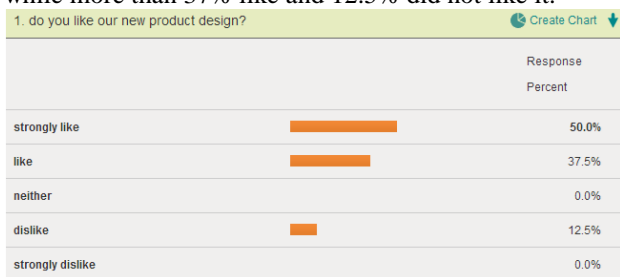


Figure 6. Results of question 1 as used for testing and validation of the proposed student's chair

The answer from the fourth question (which was related to chair's color) reflects that most of the students (about 62%) like the chair's color, whereas very few neither like (25%) nor dislike (12.5%) it. Results from the question number 4 are outlined in Fig. 7.

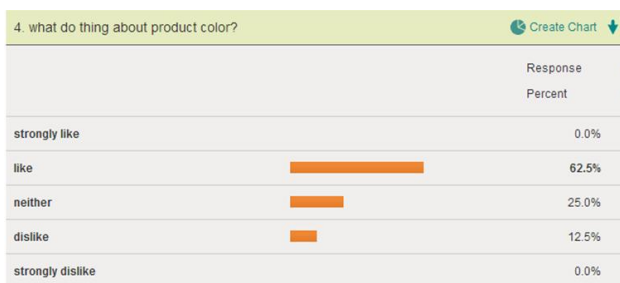


Figure 7. Results of question 4 as used for testing and validation of the proposed student's chair

The answers from the sixth question reflect that most of the students (62.5%) are concerned about the price of the chair, which seems bit costly to them. However, the students were appreciated the added functionalities of the chair such as fancy design, ease of use, comfortable seating, light in weight, etc. There is also a suggestion to reduce the price by taking several attempts such as choosing the less expensive materials, redesign the

overall structure, etc. The feedbacks from question number six is presented in Fig. 8.



Figure 8. Results of question 6 as used for testing and validation of the proposed student's chair

### VIII. CONCLUSIONS AND FUTURE WORKS

From this research study, it is noticed that majority of the students at Sultan Qaboos University, Muscat, Oman cannot find any appropriate chair with an acceptable seating arrangement in the classroom environment. Considerable numbers of students are sitting in chairs with seats and desktops that are too low or too deep. There were substantial problems between the knee height and desk clearance too. It is also noticed that, there needs different dimensions of chair for the female students as comparison to male students. Thus, it is unlikely that any classroom chair with fixed dimensions is going to accommodate a majority of students with better seating comfort and proper writing environment during lecture time.

In this research study, an innovative and ergonomically suitable classroom chair is proposed. The overall design structure of the chair and its testing and validation is also highlighted within the scope of this research. This new chair has many ergonomic features including adjustability based on students' anthropometric measures. From an intrinsic survey, it is noticed that most of the students (both male and female) strongly recommended the newly designed chair although most of them were also concern about its comparatively higher cost too. There were strong recommendations to find out ways in future version of the chair to reduce its overall cost. The basic functionalities of the chair are highly appreciated by all the students in terms of its usability with added functionalities.

From environmental point of views, it is believed that the developed chair have not any significant negative impacts on the environment. Most of the materials and/or resources were used to fabricate the chair were environmentally friendly. There were no toxic chemicals (e.g. paint, glues) and raw materials used that damage our costly environment. There were some limitations in this research study, which are needed to be carefully considered in future study of this research. For instance, the sample size of this research was only 472, which might not be suitable enough to generalize this developed ergonomics chair design. In addition, this study only considered students from a single university, which may



be extended to both college and primary school level students to generalize the design even more attractive and economically beneficial.

In future research, an updated version of the chair will be designed and developed with respect to minimize its cost structure. In addition to class room chair, an attempt can be taken to design and develop classroom chair especially suitable for disable students. This proposed chair can be updated with additional functionalities such as revolving movement, fitted with wheels to its legs for easy movement from one place to another, etc., to facilitate the users with higher comfort and additional functional needs to the students.

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