Design of Improved Nodal Classroom Chair for Ethiopian Higher Education Students to Transform Active Learning

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Abstract. A well-designed classroom chair is considered an important teaching resource to improve comfort and concentration in lecturing and peer activities of students. This research work focuses on the design of an improved classroom chair for engineering students to enhance active and conducive teaching-learning environment in Ethiopia universities. The motivation to do this research is the observed challenges and functional requirements in the classroom of many Ethiopian engineering institutes. Alternative conceptual nodal classroom chairs were sketched to reach to the final design of the classroom chair that can meet the specified requirements. The final designed nodal classroom chair was developed based on the assigned criteria's. The designed chair has four pivots to move the seat and table at the specified position to allow students during individual and peer activities. It is also developed considering the international furniture design guideline to maintain the ergonomic and anthropometric size of higher education students. In the final design of the nodal classroom chair, the critical dimensions of the average popliteal height of seat chair and table height are taken as 460 mm and 760 mm respectively based on the standard guidelines of British and EN 1729. An improved nodal classroom chair can be used to implement both lecture and Engineering drawing preparation with maximum size of A3 paper size.

Keywords: Nodal classroom chair · Design concept · Ergonomics · Active learning

Nomenclature

RHS = Rectangular hollow steel.
SHS = Square hollow steel.
CHS = Circular hollow steel.
MDF = Medium-density fiber board.

1 Introduction

Ethiopia is the second-most populous country in Africa after Nigeria, with a population of 105 million. It is also one of the least developed countries in the world, ranked 173rd

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among 189 countries on the United Nations' Human Development Index [1]. Overall enrollments in secondary education in the nation of 105 million people are remarkably low by international standards. In 2013, the British Council projected that the number of tertiary students in Ethiopia will increase by an additional 1.7 million by 2025 [1]. Ethiopia has approximately 44 operational public universities right now. In addition to public universities, there are 32 public teacher training colleges, many TVET schools, and private colleges. In 2015, there were 729,028 undergraduate students, 37,152 students in master's programs, and 3,135 students in doctoral programs [1]. However, the number of students in higher education firms is increasing time to time. Ethiopia currently aspires to become a middle-income country by 2025 and wants to use higher education as its major tool of poverty reduction and economic development. The transformation of its agriculture-led economy to an industrial economy hinges on the availability of an educated workforce that can play a critical role in technology transfer and knowledge creation [2].

To realize such a vision, facilitating the required resources for teaching and learning process in higher education firms is highly essential. The most common resources used in the classroom are furniture, black and white boards, LCD projectors, well-ventilated classroom, and other teaching aids. To transform an interactive teaching-learning process, the development of a well-designed seating nodal chair has a significant influence. Hence, improved design classroom furniture allows students and teachers to vary their routines. This has many benefits, including encouraging peer-to-peer collaboration, connections with teachers, facilitating student engagement, and offering multiple options of teaching modes. By understanding the integral role of furniture and learning mode in transforming education, the authors are motivated to design an improved classroom nodal chair that would enhance teaching and learning environment.

1.1 Teaching Practices in Higher Education Institute of Ethiopia

In Ethiopia, the main course delivery methods in higher education universities include lectures, tutors, and experimental sessions according to the course guide book. The existing classroom furniture found in many universities are stationary armchairs, combined seats and desks, heavy chairs, and tables that do not allow students to interact easily. Students are even doing engineering drawings in such non-conducive working table. This situation hinders students' performance and understanding capacity of them. However, the instructors are interested to give peer group activities in the classroom, the arrangement of chair and tables for this purpose is time taker and tedious process. The design and development of portable, flexible furniture is required to enhance student-centered learning processes. The main objectives of designing and upgrading classroom chairs are to encourage interactive learning, provide comfortable sitting with larger work surfaces, improve functional relationships, increase flexibility to respond to future needs, increase classroom use rates, and increase students and teachers motivation in the learning and teaching process. Figure 1 below presents the teaching-learning scenario with an armchair seat in Bahir Dar Institute of Technology.

The armchair seat shown in Fig. 1 does not allow students to interact during group activities at the expected level, and also it is time taker to move and arrange thus chairs to apply different modes of teaching- learning processes.

a. Trainees sitting conditon during lecture time.

b. Trainees sitting conditions during group

Fig. 1. Existing classroom armchair at Bahir Dar Institute of Technology, Ethiopia.

1.2 Effect of Classroom Furniture on Active learning Environment

Active learning classrooms were identified as a top strategic technology and are more or less flexible depending on the type of furniture used. Furniture plays a vital role in the environment of active teaching and learning process. Proper usage of an ergonomically classroom chair is needed for the maintenance of good health, improvement in academic performance, active learning and motivation [3]. Improperly designed furniture, ill-fitted to the characteristics of a student can result in faster fatigue, defective posture, and the establishment of pathological states that could affect their performance in focusing in class [4, 5]. Classroom chairs could support body weight and enable postural movement and circulation [6]. On average, students spend a quarter of the day at school and 80% of the school time is mostly in the sitting position. Therefore, ergonomically precise sitting posture is an important factor for the elimination of musculoskeletal symptoms [7].

2 Methods and Design Considerations

2.1 Methods

To conduct this research work, the following methods and methodologies are applied.

1. A survey was conducted through observation and physical measurement of the avail classroom chairs which were used by students in higher education institute of Ethiopia, Bahir Dar institute of Technology to compile information for further improvement of the design of classroom chair. The existed overall dimension of armchair has 65 cm length, 65 cm width and 88c m height as shown below on Fig. 1.

The armchair was fabricated from an oval shape steel pipe (20 mm * 30 mm * 1.25 mm), round steel pipe (outer ø 22 mm and wall thickness 1.25 mm) and laminated plywood which has 10 mm thickness. The actual measured dimension of each part of the chair is shown below on Table 1.

The available armchair which was shown on Fig. 1 is used for theoretical lecturing and also teaching technical drawing for extension engineering students in Bahir Dar

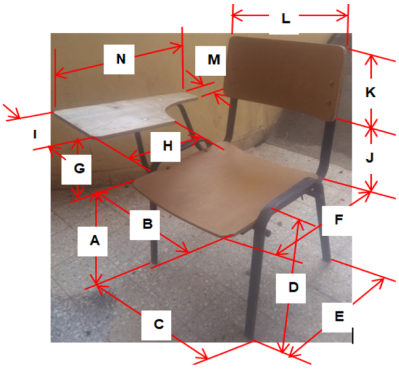


Fig. 2. Physical shape and dimension of armchair (Source: the picture was captured in Bahir Dar institute of Technology, February 2020).

Table 1. Measured dimensions of classroom armchair in Bahir Dar Institute of Technology.

Measurement designation	Name of the measurement	Measurement values (cm)
A	Popliteal height	41
B	Seat length (buttock-popliteal length)	45
C	Base length	52
D	Stand height	46
E	Stand bottom width	45
F	Stand top width	30
G	Height between seat and arm table	25
H	Short length of arm table	27
I	Width of arm table	28
J	Height between seat and back support	22
K	Height of wooden back support	25
L	Length of wooden back support	48
M	Narrow width of arm table	10
N	Length of wooden arm table	50

Institute of Technology. However the chair is not convenient for left-handed students and to prepare technical drawing (Fig. 2).

2. Literatures was assessed and reviewed from previous scientific research.
3. Developing alternative design concepts and screening out the best design.
4. Applying CATIA software for modeling and preparation of working drawing.

Generally, to fulfill the actual functional requirement of the designed chair, the current scenario of teaching -learning methods, used resources, and teaching aids are considered.

2.2 Design consideration

2.2.1 Design Requirements

The design of classroom chairs are done by considering students' requirements, functional requirements, and technical requirements to support interactive teaching and learning activities. The final design of this nodal chair should be ergonomically safe, robust, comfortable, moveable, and rotary in all directions of classmates to apply variable teaching methodology in the classroom. In addition the chair is not only lecturing purpose but also useful for practicing engineering drawing by using the size of A4 and A3 drawing paper. It also has material keeping case to handle books, bags, drawing instruments, water bottles, pencils, and pens to create conducive situations during teaching and learning process.

2.2.2 Ergonomic Consideration

Ergonomics is an engineering profession that applies theory, principles, data, and methods for understanding the interaction between humans and equipment to optimize conducive and safe working environments [8]. Anthropometry is a science that deals with body measurements, where the measure body length, shape, strength, and working capacity [9]. Ergonomic considerations in classroom chair design give many qualitative and quantitative advantages such as reducing developmental lead-time and cost, increasing user comfort and reliability [10, 11, 15]. The functional utility of the student's classroom furniture is a result of its physical design in relation to the physical structure and biomechanics of the human body. Hence, the key anthropometric dimensions shown in Fig. 3 (1–12) are considered in our chair design procedures (Table 2).

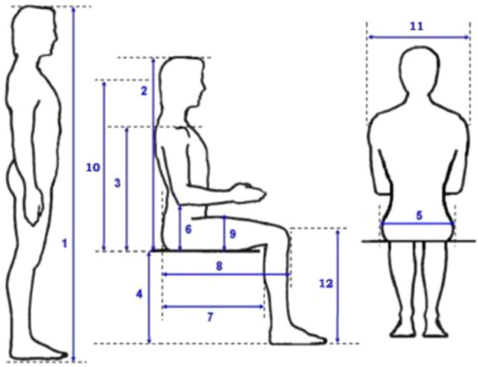


Fig. 3. Key anthropometric dimensions required for chair design [16].

The chair dimensions shown in Fig. 4 are a general-purpose chair to be used by any adult [12]. All elements of the chair must be planned. The seat height is determined by

Table 2. Anthropometric dimensions and their description.

No	Designation	Descrption
1	Stature	The vertical distance from the floor to the crown of the head
2	Sitting height	Height between seat and Top of the head in a normal relaxed posture
3	Sitting mid shoulder height	Height between the seat and level of the shoulder
4	Popliteal height	Height of the underside of the thigh immediately behind the knee
5	Hip breadth	Maximum horizontal distance across the hips
6	Elbow rest height	Distance between seat and lower most part of the elbow
7	Buttock-popliteal length	Horizontal distance from the most posterior point on the uncompressed buttocks to the back of the lower leg at the knee
8	Buttock knee length	Horizontal distance from the most posterior point on the uncompressed buttocks to most anterior point on the knee
9	Thigh clearance	The vertical distance from the seat surface to the maximum bulge on the anterior surface of the thigh was measured with a shortened anthropometer
10	Sitting eye height	Height of inner corner of the eye sitting in normal relaxed posture
11	Shoulder breadth	Maximum horizontal distance across the shoulders
12	Knee height	Height of uppermost point on the knee

the popliteal height measurement "4" in Fig. 3. The popliteal height is the measure from the floor to the back part of the leg behind the knee joint while seated.

In designing for a known individual, one's own body dimensions may be measured and used. However, for mass application, the percentile values of a study population are usually required.

Therefore, in design application, different percentile values of different dimensions may be necessary even on a simple design solution. Lower percentile values are considered for accommodating the maximum number of people having higher values, where easy reach is the concern. Higher percentile values are considered where the maximum number of population having lower values cannot reach the level, as required in ensuring safety and ease of operation [13, 16, 17].

In This study, we are applying the general guidelines of British and European Standards for furniture design rather than using anthropometric measured data's. The British and European Standards for chairs and tables design for an educational institution was approved in January 2007. BS EN 1729 Part 1 (functional dimensions) ensures furniture to be appropriate size, shape and ergonomic design to maintain good posture and reduce Repetitive strain injury (RSI) and back pain in students. This size mark guide for higher

education adult students indicates the fixed seat heights and table heights of suitable chair for the student's age as shown on Fig. 4 below [14].

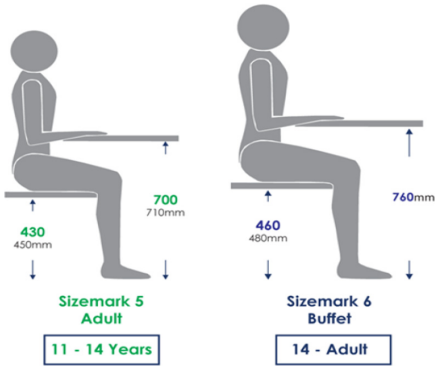


Fig. 4. Recommended chair and table size for design guide, EN1729 [14].

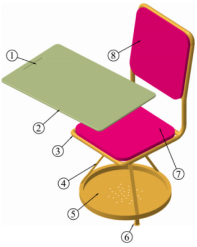
Since the fixed popliteal height and table height are mainly considered for improved nodal chair development. The average popliteal height of seat chair 460 mm and table height 760 mm indicated in Fig. 3 leads the author to generate a new design concept and to determine the average size of nodal classroom chair for engineering students to meet the specified objectives.

2.2.3 Design Concept Generation

The design idea of an improved nodal classroom chair is generated after analyzing all the requirements and observing the challenges faced in the classroom. For better interactive teaching and learning environments, the design should allow the chair to be moveable easily in any place of the class, and also the chair should allow the students to interact with their near classmates in all directions by rotating easily. In addition, the chair should function engineering students to do engineering drawing by handling all required materials safely and conveniently. In this stage, four different nodal classroom chair concepts were generated based on the major requirements. Each conceptual classroom chair design has its own design features and functions. The four conceptual chair designs are presented in Fig. 5 below with their brief descriptions.

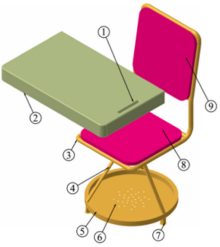
The conceptual designs shown above on Fig. 5 are designed by targeting the specific purposes of comfort, ergonomic and safety, learning material handling, drawing practice, and peer learning. The nodal classroom chairs have four rotating pivots to allow rotary degrees of freedom for better interaction of students without wasting time. The designer considers the movability of the seat and table to adjust it to the convenient position during writing and drawing. The parts shown in the conceptual design from 1 to 9 are described as pen and pencil tray, table, seat frame, load support, base and material handler, foot (caster wheel), seat wood, and back seat respectively. The four conceptual designs are described below shortly.

Concept Design 1(cd1). The nodal classroom chair shown in Fig. 5a is designed to be fixed on the floor with fisher and screw. However, the seat and the table are easily

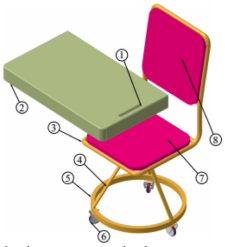


a. Nodal classroom chair conceptual design 1. (1. Pen and pencil case, 2. Table, 3. Seat frame, 4. Leg, 5. Material case, 6. Foot, 7. Laminated wood seat, 8. Back support)

b. Nodal classroom chair conceptual design 2. (1. Pen and pencil case, 2. Table, 3. Table stand, 4. Leg, 5. Material case, 6. Perforated hole for waste removal, 7. Caster wheel, 8. Seat, 9. Back support)



c. Nodal classroom chair conceptual design 3. (1. Pen and pencil case, 2. Table, 3. Table stand, 4. Leg, 5. Material case, 6. Perforated hole for waste removal, 7. Foot, 8. Seat, 9. Back support)



d. Nodal classroom chair conceptual design 4. (1. Pen and pencil case, 2. Table, 3. Table stand, 4. Leg, 5. Base, 6. Caster wheel, 7.seat, 8. Back support)

Fig. 5. Conceptual design of alternatives nodal classroom chairs (a–d).

rotated for convenient sitting and peer learning. In addition, this design includes learning material handling at the base of the chair.

Concept Design 2(cd2). The conceptual design shown in Fig. 5b is similar to conceptual design 1 except for the replacement of caster wheel to allow the movement of degree of freedom of the chair to go to at any place in the classroom for the intended purpose.

Concept Design 3(cd3). The additional features of conceptual design 3 over concepts 1 and 2 are teaching material drawer with table. This may help students to manage their learning materials easily and safely.

Concept Design 4 (cd4). The conceptual design 4 is similar to conceptual design with all features except the replacement of a fixed foot with a caster wheel. This might help students to move any place in the classroom to interact with other students or other planned purposes. The major differences between the four conceptual designs lie in the portability and teaching material handling convenience. However, the selection of a better design will be done using a design concept screening technique.

2.2.4 Design Concept Screening

The concept screening is a method used to sort out the number of concepts to reach to improved design concepts. This step was completed by comparing the merits and demerits of the generated concepts based on the specified selection parameters. In concept screening process, if any of the conceptual design of the chair is better than the other conceptual design and existed armchair, it is marked by a plus sign. On the other hand, a negative sign is used for the worst design than other alternative designs. The 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. Major selection criterions such as ergonomics and safety, ease of use, ease of manufacture, durability, and aesthetics are considered for refining purposes. Table 3 was used to rank the concepts and to choose the best one. The process follows the six basic steps to reach to final decision. These steps are preparing the selection matrix, rating the concepts based on selection criterions, ranking the concepts based on summed scores, combining, and improving the concepts, selecting one best concept and reflecting on the results, and the process.

Table 3. Design concept screening out matrix.

No	Selection parameters	Alternative conceptual design			
		Cd1	Cd2	Cd3	Cd4
1	Ergonomics and safety	+	+	+	+
2	Manufacturability	+	+	+	+
3	Material availability	+	+	−	−
4	Comfortably	+	+	+	+
5	Stability	+	−	+	−
6	Durability	+	+	+	+
7	flexibility	+	+	+	+
8	Aesthetic	+	+	+	+
9	Space saving	+	−	+	-
10	Maintainability	+	+	+	+
11	Cost	+	−	+	−
	Sum of "+"s	11	8	10	7
	Sum of "−"s	1	3	2	4
	Net score	10	5	8	3
	Rank	1st	3rd	2nd	4th

*Cd = conceptual design

From Table 3 above, the design screening out matrix shows that conceptual design 1 is more preferable than other alternative design concepts depending on the assigned criterions. Thus final designed nodal classroom chair will be fixed on the floor and can be implemented on small area of classroom. On this chair, the students are able to draw

any given working drawing with A4 and A3 paper. The chair also allows students to rotate in directions of their classmates for discussion and other peer activities.

2.2.5 Material Selection and Fabrication

The final design of the nodal classroom can be fabricated from locally available materials such as RHS, SHS, CHS, black sheet iron, and MDF wood, with the expected strength and functional requirements. The designed nodal classroom chair can be manufactured in small and medium metal manufacturing industries. The major manufacturing processes to be applied are cutting, pipe bending and rolling, welding, drilling, finishing, and assembling by using basic tools and machineries. Table 4 below presents the required raw materials and estimated cost to fabricate the final design nodal classroom chair.

Table 4. Main raw materials and estimated cost for nodal classroom chair fabrication.

No	Item description with technical specification	Unit	Qty	Unit price (ETB)	Total price (ETB)
1	RHS (20*40*1.5) mm, length = 300 cm	pcs	1	200.00	200.00
2	Black sheet iron, dimension:(500*500*1) mm	pcs	1	75.00	75.00
3	SHS (25*25*1.5) mm, length = 400 mm	pcs	1	24.00	24.00
4	CHS: O. diameter = 43 mm, I. diameter = 35 mm, L = 100 mm	pcs	1	10.00	10.00
5	CHS: O. diameter = 33 mm, I. diameter = 28 mm, L = 200 mm	pcs	1	20.00	20.00
6	CHS: O. diameter = 50 mm, I. diameter = 44 mm, L = 100 mm	pcs	1	15.00	15.00
7	CHS: O. diameter = 27 mm, I. diameter = 23 mm, L = 160 mm	pcs	1	10.00	10.00
8	MDF Wood for table part:(75 * 45 *1.6) cm	pcs	1	45.00	45.00
9	Laminated ply-wood for seat: (40 *45 *1.2) cm	pcs	1	50.00	50.00
10	Laminated ply-wood for back seat: (40 *25 *1.2) cm	pcs	1	40.00	40.00
11	Flat iron: (40 *4* 120) mm	pcs	1	15.00	15.00
12	Snap head bolt and nut: M6, length = 40 mm	pcs	4	10.00	40.00
13	Electrode, diameter 2.5 mm	pkt	0.1	220.00	22.00
14	Cutting tools			100.00	100.00
15	Paints			150.00	150.00
	Estimated total material cost				816.00
	Labour cost				800.00
	Overhead cost				200.00
	Miscellaneous cost				200.00
	Total selling price				2016.00

The modified nodal classroom chair was adapted from the existed acrylic modern classroom chair with desk which is used abroad. The nodal chair is possibly developed from available materials in the local market of Bahir Dar Ethiopia. The estimated selling price of the modified nodal classroom chair will be 2016.00 ETB. This price is lower when we compare to the price of armchair which is currently sold with 60USB (2100.00 ETB) used in the classroom of Bahir Dar Institute of Technology. It would also benefit the manufacturer of local enterprises and end users by reducing foreign currency.

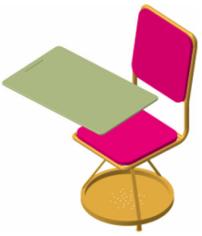
2.2.6 Working Principles and Assembly Technique

The designed nodal classroom chair has an overall dimension of 50 cm * 50 cm * 85 cm. The popliteal height and table height from the floor is approximately 46 cm and 76 cm respectively, to meet the average ergonomical size of higher education students. The chair has three principal parts which are base sub-assembly, seat sub-assembly and table sub-assembly. The base assembly is fixed to the floor with fisher and screw by maintaining the perpendicularity of the post part. Next to base fixing, the table sub-assembly is fitted to the post of the base by sliding the table bush over it with close clearance assembly. Finally, the seat sub-assembly is fitted between the table hub and the base post with close clearance. These assembling techniques allow the seat and table to rotate in the required position of the student. Hence the movability of the chair facilitates student-centered learning easily by saving time and it also motivates students and teachers because of its conducive features for a variety of teaching pedagogy.

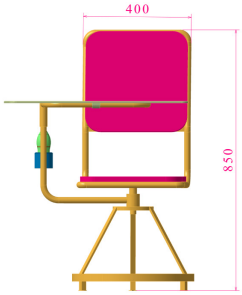
3 Result and Discussion

The final design of nodal classroom chair will play the vital role for facilitating student-centered learning. It has a capacity to rotate in all directions of classmate to share ideas and to perform peer activities in comfort seat. It is also designed by considering the basic criteria and requirements to minimize the existing challenges in the classroom. Figure 6 below presents the features of the final design of classroom chair and its assembly order.

The chair can be manufactured from available materials in the local market by maintaining its strength and functional requirement. The designed chair functioned as seat and comfortable table for both lecturing and also practicing of drawing for higher education engineering students. The major subassembly units can be assembled within a minute without using temporary fasteners.

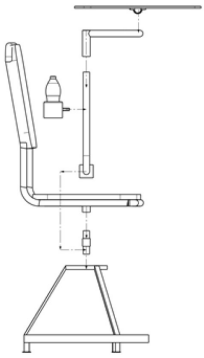


a. 3D Drawing of designed nodal classroom chair.



b. Frontal view of designed nodal classroom chair.

c. Side view of designed nodal classroom chair.



d. Assembly flow of designed nodal classroom chair.

Fig. 6. Final design features of nodal classroom chair (a–d).

4 Conclusion and Future Work

Classroom chairs is one of the basic inputs to run teaching –learning activities. Many studies indicated that well-designed classroom furniture has a positive influence on students to understand the subject matter and to keep them from fatigue problem. As developing comfortable educational classroom chair should also support the learning activities of the students. Therefore school furniture should be able to facilitate learning by providing a comfortable and stress-free workstation. It could help us to prevent discomfort, inappropriate sitting postures and occurring musculoskeletal disorders, conclusively increasing efficiency in schooling situations. Hence, the following conclusions are drawn from the final design works of nodal classroom chair.

1. The existing armchair in the classroom does not allow changing the traditional teaching pedagogy because of its inconvenience for required arrangements.
2. The newly designed nodal classroom chair is developed by following the international furniture design guide line to maintain the average anthropometric size of higher education students and also considers the functional requirements in the classroom in Ethiopia such as peer activities and practicing of engineering drawing.

3. The high degree of freedom of movement on the table and seat part of the designed chair allows students for better interaction between them for the given instruction and other activities.
4. In general, the screen out designed classroom chair is affordable, comfortable and fulfills the functional requirements of higher education students in Ethiopia if it is implemented as per the design specification.
5. In future studies, anthropometric measurements, cost reduction techniques on the designed nodal chair should be further studied to implement in all stage of Ethiopian students by including the major facilities on the classroom chair.

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