# ERGONOMICS EVALUATION OF DESIGN STUDIO AT FKM UTeM

**MUHAMMAD IRSYAD BIN AHMAD KHAIRI**

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**in fulfillment of the requirements for the degree**
**Bachelor of Mechanical Engineering (Hons.)**



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**DECLARATION**

I declare that this project report entitled "Ergonomics Evaluation of Design Studio at FKM UTeM" is the result of my own work excepts cited in the references

Signature : ……..

Student's Name : ……..

Date : ……..

**APPROVAL**

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons).

Signature : ……..

Supervisor's Name : ……..

Date : ……..

**DEDICATION**

To my beloved father, Ahmad Khairi B. Yahya

and my mother, Hajijah Bt. Ahmat

## ABSTRACT

Ergonomics is the way to plan or organize workplace environments structure and systems to fit the users so that any harmful pains will be reduced. Ergonomics applies to the design of everything including work areas, sports and relaxation, wellness and personal safety which promote health and safety and maximizing productivity. Attention to the principles of ergonomics helps to decrease accidents and disorders in the workplace, resulting in compensation expenses for employees, medical claims and loss of working time. The aim of this project is to design and analyse student's body posture at the workstation during studio activities by using CAD software design CATIA V5R20. It is used for 3D modelling and ergonomics analysis. In this project, there are three concepts that have been proposed and the selection method used to find out the best concepts for further detailed design in the next step. The best designs of the concept were selected based on criteria stated in the evaluation of Pugh Selection Matrix and Weighted Decision Matrix. Selection design was analysed using Rapid Upper Limb Assessment (RULA) to achieve the results of ergonomics analysis. The final ergonomics score indicates a score of 2 for the new selection model. The new selection structure guarantees that the user's body is in a secure and stable place to lower back, neck and hip joint stress.

## *ABSTRAK*

*Ergonomik adalah cara untuk merancang atau menyusun struktur dan sistem persekitaran tempat kerja agar sesuai dengan pengguna supaya sebarang sakit berbahaya dapat dikurangkan. Ergonomik diguna pakai terhadap reka bentuk semua termasuk kawasan kerja, sukan, kesejahteraan dan keselamatan individu yang menggalakkan kesihatan dan keselamatan dan memaksimumkan produktiviti. Fokus terhadap prinsip ergonomik membantu mengurangkan kemalangan dan gangguan di tempat kerja, menyebabkan perbelanjaan pampasan bagi pekerja, tuntutan perubatan dan masa bekerja. Tujuan projek ini adalah untuk merekabentuk dan menganalisis postur badan pelajar di stesen kerja semasa aktiviti studio dengan menggunakan reka bentuk perisian CAD CATIA V5R20. Ia digunakan untuk model 3D dan analisis ergonomik. Dalam projek ini, terdapat tiga konsep yang telah dicadangkan dan kaedah pemilihan digunakan untuk mengetahui konsep terbaik untuk reka bentuk terperinci lebih lanjut dalam langkah seterusnya. Reka bentuk terbaik konsep dipilih berdasarkan kriteria yang dinyatakan dalam penilaian Pugh Selection Matrix dan Weighted Desicion Matrix. Reka bentuk pemilihan dianalisis dengan menggunakan Rapid Upper Limb Assessment (RULA) untuk mencapai keputusan analisis ergonomik. Berdasarkan skor ergonomik ianya menunjukkan skor 2 untuk model pemilihan baru. Struktur pemilihan baru memberi jaminan kepada pengguna agar sentiasa berada di tempat yang selamat dan stabil untuk leher dan pinggang.*

## ACKNOWLEDGEMENTS

Alhamdulillah, thanks to Allah S.W.T for giving me the ability to finish this project. Deep in my heart, I also thanked to my beloved parents that always pray for my journey to be an engineer. A special thanks to my supervisor, Dr. Shafizal Bin Mat, who guided me throughout the process of completing this report.

Next, I would like to express my gratitude to all my friends and anyone who always motivates me to cooperate in commenting, opinions and directly or indirectly supporting me. Hopefully this thesis will be useful in future as a guide for a student as their reference in further study.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Ergonomics commonly referred to as human factors that apply physiological principles to product, process and system design. Ergonomic issues can be related to a wide variety of concerns including workstation physical outline, work environment, tools, vehicles, computer programs and plant. Ergonomics aims at designing equipment, technical systems and tasks to improve human health, safety, comfort and results. Human components are aimed at reducing human error, increasing productivity, and enhancing safety and comfort with a focus on human interaction. Ergonomics is the way to plan or organize products and systems of working environments to fit the people who have used them. Ergonomics applies to the design of everything including working spaces, sports and relaxation, well - being and security for individuals. In order to reduce and minimize the risk of injury or harm, ergonomics aims to improve workplaces and environments (Kroemer Elbert et al., 2018)

Productive workspaces, which involve the design of a workspace with human capacity and limitation, including body measurement, sensory abilities (vision, hearing) and even attitudes (Gurr, K., Straker et al.,1998) hazard is basically the potential for harm or harm to people's health, loss of equipment, and environment. Ergonomic hazard is a physical factor that damages the musculoskeletal system within the environment.

Ergonomic hazards include issues such as uncomfortable workstation height, poor positioning of the body, extreme postures, repetitive movement, poorly designed tools, handling and physical environment. Hazards often result from the design of the space, which means that it is crucial to plan ahead and think about how employees interact with their workspace. The importance of ergonomic hazards depends after a period of time on the level of exposure. Injuries sustained from these risks can be anything from sore muscles to long haul diseases.

Poor worksite design results in students being tired, frustrated, and hurt. This rarely results in the students being the most productive. It is more likely to cause painful and costly injury, lower productivity and poor product quality. The physical outline of workstations and other equipment has a great pattern of ergonomics, which can affect the student's own health and productivity (Zetterberg, Heiden et al.,2019). The use of ergonomic workstations in the design studio environment is likely to lead to reduced body discomfort and a positive effect on performance. Users of workstations that are mainly students use similar workspace for each class they attend Their desk, chair and workspace design can be given specific ergonomic consideration.



## 1.2 Problem Statement

The most important consideration when designing the ergonomics design studio is individual started to develop several musculoskeletal injuries when using the computers in extended period of time and the cause was poor design of their workspace. There are few factors play a role in ergonomics, including body posture and movement (sitting, standing and pushing), noise, climate and vibration environmental factors, as well as organization of work scope. Many individuals do not understand that severe health issues can result

from a badly constructed computer workstation and/or poor job habit. Common symptoms connected with bad design or practices include back, neck and shoulders pain, hands and wrists, headaches and eye strain (Jeffrey R. Cram, I. Vinitzky, 1992).

For prolonged periods of time, the work needs individual to sit at the desk for several hours. Mainly sedentary days spent put individuals at risk for chronic pain, musculoskeletal disorders and accidents, all of which have an effect on long-term health and productivity (Candotti, Detogni Schmit et al.,2018) "Sitting disease" is a phrase lately created as fresh study indicates that sitting without proper posture and spine alignment for lengthy periods of time can lead to several long-term health circumstances, including musculoskeletal disorders. Poor work site layout results in individuals being tired, frustrated, and hurt. This rarely leads to the individuals being the most productive. More probably, it results in painful and costly injury, reduced productivity and bad quality of the product (Kroemer Elbert et al., 2018)

## 1.3 Objectives

The purpose of this study is to conduct the evaluation of Faculty Mechanical Engineering design studio which focuses on the ergonomics system. The study is to analyze and identify the ergonomics principle used in the design studio. Particularly, the objective is to:

1. To design and create ergonomics workspace of design studio by using computer software SketchUp.
2. To analyses student ergonomics body posture at workstation during studio physical activities.

## 1.4 Scope of Project

The project's scope outlined for this project are:

1. The design of ergonomics studio satisfies the safety requirement including not harmful to the users, considerable persistence and environmentally friendly by applying initial analysis on the design.
2. This project focus on analyzing body posture of individual at the workplace of design studio.
3. Design and analyze the conceptual design using Computer Aided Design software (RULA) and analytical software.

## 1.5 General Methodology

The method and flow of works that are used to accomplish this project is discussed on the next chapter. The actions needed to achieve this project's objectives are listed below:



### 1.5.1 Literature Review

Any material such as journal, book, article, website or video, will be used to gain knowledge of the existing research related to the particular topic and analyze the information that have been gathered to improve the research or project.

### 1.5.2 Method of Gathering Information

The study will also include data collection methods. The questionnaire collects the data. In answering these research questions, statically weighted decision matrix was used. The questionnaire designed for the study was subjected to the students especially on the ergonomics concept design of the studio.

### 1.5.3 Ergonomics Studio Design

The study will include the human - related ergonomics risk factors and their nature of work in order to gain a better understanding of the mechanism of ergonomics, parts, and any other information related to the subject. Class layout and size capacity shows the adequate amount allowed in a classroom or design studio.

### 1.5.4 Workstation Design

A simple workstation is created by using analytical software Sketch Up to achieve the objective. Analysis the movement and posture of individual is done by using suitable software Rapid Upper Limb Assessment analysis. RULA Analysis allows individual to choose optimize posture according to postural score. The final score will show an indicator score value of the ergonomics design whether it achieve the target or not.

### 1.5.5 Final Report

A final report was written after all of the design analysis works were successfully done.

## 1.6 Organization of Report

The project background, problem statement, goals, scope and general methodology were captured in this introduction chapter. The project background describes the entire project introduction. In this project, the most important thing is to achieve the project goals. The project scopes explain the project boundary and target users. This topic also covers the needs and content of this project. Output and approach used in this project are explained by the general methodology.

The next chapter will discuss on literature review and methodology. Previous research and findings related to this project will be described in the literature review. It will help to develop and improve the proposed project. In the meantime, the methodology will cover the selected approach to the development of this project as it helps to complete the project with the project's progress schedules and the necessary requirements. Methodology illustrates the method on how the ergonomic analysis is implemented. The methodology is required to produce a systematically and orderly research plan in order to smooth out the report progress.

Conceptual design is the first step in creating a new product in the multi-phase process. The conceptual design phase follows the schematic design characteristics and morphological chart helps to illustrate method and strategy in developing the concepts generation. For the engineering analysis chapter, selection design was analyzed using Rapid Upper Limb Assessment (RULA) analysis to achieve and obtain the result of ergonomics analysis. The result shows the individual work-value and final score of the conceptual design posture.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Ergonomics

Ergonomics is the way to structure or organize work environments, products and systems to fit the people using them. Ergonomics or human variables as referred to in North America are part of science aimed at finding out about human capacity and constraints and then applying this understanding of how individuals can cooperate better with products, structures and environments. Ergonomics plans to improve workspaces and situations in order to reduce the risk of harm or damage (Kroemer Elbert et al., 2018). The need to make sure that as technology changes, the devices we access for work, rest and play are tailored to the needs of our body. An orderly ergonomics-enhancing process inspects hazard factors that result in injury to the musculoskeletal system and considers increased human performance and productivity (John R. Wilson, 2000).



Ergonomics is a combination of the words ergo, a Greek word meaning “work” and nomics, meaning “study” – the study of work. An applied science that coordinates the design of devices, systems and physical working conditions with the capacities and requirements of the workers (N. Jaffar et al.,2011). Ergonomics is intended to ensure maximum productivity at a minimum cost; in this context, costs are expressed as workers ' physiological or healthcare costs. Only a large number of tasks in a working environment sometimes exceed most of the workforce's skills. There may be jobs that include a specific

task that requires extended reach or overhead work that cannot be sustained for long periods of time by using ergonomic standards to plan those undertakings, more people should be able to do the job without the risk of damage. Ergonomics has already been defined and the focus is primarily on the design, skills and limitations of the individual-friendly work activities (Karwoski,1991). The approach is to respond to an individual skill requirement to reduce the risk of manual handling and material handling of musculoskeletal wounds.

Martin Helander (2006) defined that ergonomics is rarely a goal in itself. Safety, operator satisfaction and productivity are common goals of ergonomics. Ergonomics is a design methodology that is used to arrive a safety, productivity and satisfaction, the safety status of a system may be assessed by comparing the performance requirements of the environment with the performance limitations of the operator.

### 2.1.1 Human Factors and Ergonomics (HFE)

Human variables and ergonomics are commonly known as human elements and the application of psychological as well as physiological standards to product, process and system design. Human elements are intended to reduce human error, increase productivity and improve safety and comfort, with a focus on human interaction. Human factors represent the health, safety and profitability objectives of the workplace. It is important to design things like safe furniture and easy to use interfaces for machines and appliances (Martin Helander,2006)

Suitable ergonomic design is necessary to prevent repeated strain injuries and other disorders of musculoskeletal injury that can develop over time and lead to long term disability (Chapanis, 1995). For an assessment of a person's fitness with the technology being used, human factors specialists and ergonomists consider both

the work being done (activity) and the needs of the user; the equipment being used (the size, shape and how it is suitable for the task). Ergonomics focuses on many disciplines, including visual design, user knowledge, biomechanical, mechanical engineering, industrial design and information design, in its study of humans and their environment.

Human elements and ergonomics relate to the user's fit, equipment and environment. It represents the user's capabilities and limitations to ensure user-friendly tasks, capabilities, information, and environment. Human factors specialists or ergonomists consider the work being done and the requirements of the user; the equipment used (size, shape, and how appropriate it is for the task) and the information used (how it is introduced, accessed, and changed) to assess the fit between an individual and the innovation used (Chapanis,1995). Ergonomics uses many orders, including mechanics, industrial engineering, information design and design, in its human and environmental studies.



### 2.1.2 Importance of Ergonomics Evaluation

In order to adapt them to the general public, ergonomics plan or organize work environments, items and frameworks. The vast majority have knowledge of ergonomics and believe that it concerns the structure of the workplace, sports and relaxation, well-being and safety, or the design of car controls and instruments. Ergonomics is a science that involves learning human capabilities and constraints and applying this knowledge in order to improve interaction between human beings and products, systems and environments. Ergonomics is designed to improve working spaces and environments to minimize the risk of harm or injury (Kroemer Elbert et al., 2018).

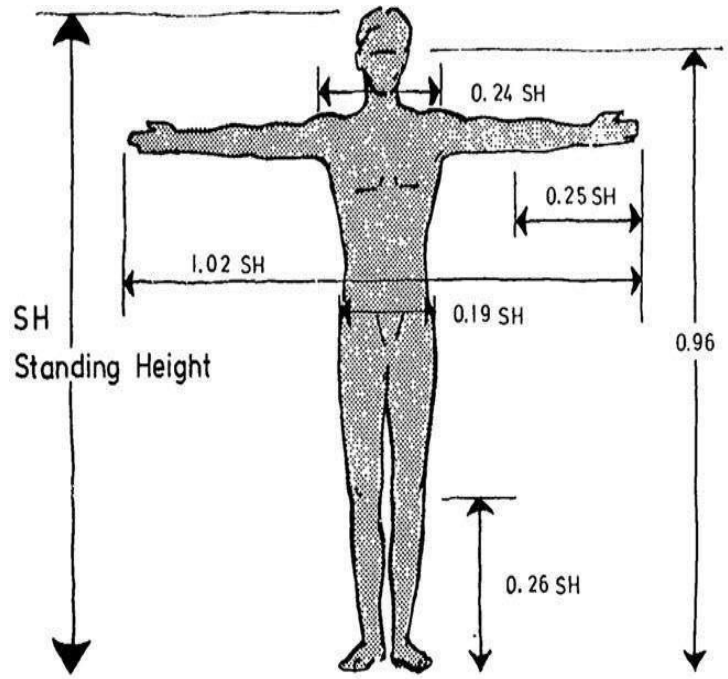



**Figure 2.1**: Human Ergonomics System (Source: Dhorman Consulting,2010)

### 2.1.3 The Social Value of Ergonomics

Ergonomics can add safety, well-being and comfort to human well-being. Human errors, such as workplace accidents, traffic and home accidents, as well as disasters involving cranes, aircraft and nuclear power plants, can often be referred to daily. The likelihood of accidents can be reduced if human capacity and limits are better considered when designing the work environment and everyday life. Ergonomics has become one of the most important design factors in reducing operator errors by designing complex technical systems such as installations, aircraft and power stations (John R. Wilson, 2000).

Many working and regular day-to-day situations are unsafe for health. In many countries, diseases of the musculoskeletal system (mainly lower backpain) and psychological disease. These conditions may be related in part to the structure of the hardware, technical system and tasks. Ergonomics can help the problem by

improving working conditions. Therefore, in a number of countries, occupational health and safety regulations refer to ergonomics as a means of preventing work-related health problems by improving working conditions. Dhorman conslt, (2010) mentioned that some ergonomics knowledge has been compiled into official standards to stimulate the application of ergonomics and prevent the health problem.

Ergonomics helps make products that are user-friendly. Many customer products, for example, are promoted as ergonomically, suggesting comfort and enjoyment during product use. Ergonomics at company level can contribute to a company's competitive advantage. Cynthia Roth, (2011) defined by ergonomically designed production processes, a company can increase human performance in terms of productivity and quality and significantly cut costs. A company can offer its customers benefits with products that are ergonomically designed that exceed those of competing products.



### 2.1.4 Physical Ergonomics

Karen Shor, Chauncey Wilson, (2011) stated that physical ergonomics addresses human life structures and some of the attributes associated with physical activity. In the design of mechanical and consumer products, physical ergonomics, physical ergonomic standards have been widely used. In the medical field, for diagnosis of physiological diseases or conditions such as chronic and carpal tunnel disease, physical ergonomics is particularly important. The most common type of work-related injury is musculoskeletal pain disorder. Many ergonomically designed products are also used or recommended for treatment or disorder prevention and treatment of massive pressure pain. Work-related skeletal muscle disorders

(WRMDs), but their initial diagnosis is difficult, mainly due to pain and other symptoms, resulting in pain persistence, loss of usefully limited and occupational disability. Some jobs or working conditions lead to more complaints of unnecessary strain, wear, discomfort or pain from employees after night. These jobs include regular slow, hard work, frequent, heavy and overhead lifts, discomfort or vibrant use of equipment (Yamayu, 2013).

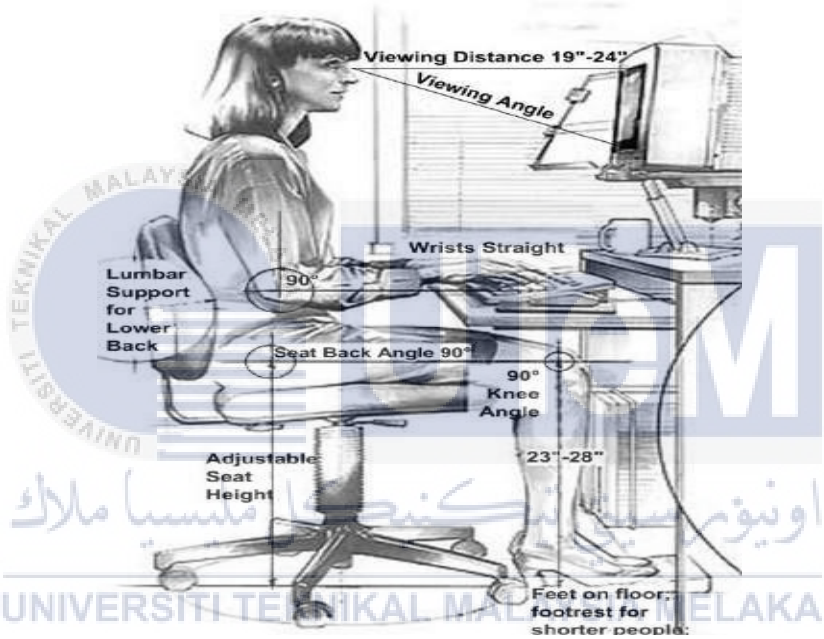



**Figure 2.2**: Human Physical Ergonomics (Source: Yamavu, 2013)

### 2.1.5 Ergonomics Principles Contribute to Good Workplace Design

The objective of the work environment is to design and understand the ergonomics of posture and development that are essential for a safe, conducive and comfortable work environment for as many people as possible. The design of the workplace should be aimed at stimulating the spirit of teamwork among others and, more importantly, providing a safe environment. The task and the workplace will manage posture and movement and will be involved in the adoption of the body's

posture, movement and application of force, muscles, tendons and joints. Poor posture and development of muscles, tendons, ligaments, and joints can contribute to the local mechanical stress that causes neck, back, shoulder, wrist, and other parts of the skeletal system. The muscles have the strength to hold or move around to perform the routine of everyday work (Elsevier Ltd, 2013).

## 2.2 Posture

Nico J. Dellman (2004) stated that the position an individual take in performing a specific task is controlled by the relationship in the workplace of the person between the elements of the body and the components of various things. Therefore, the extent to which the position is limited depends on how many associations or interfaces there are between the person and the work site and the nature of them. The connections can either be physical, such as sitting, workstation, floor or visual, such as display gaze direction. If maintained for long periods of time, each body position can cause discomfort and fatigue. However, working for long periods in a standing position can cause sore feet, general muscle tiredness, and low back pain. Furthermore, inappropriate layout of work areas and certain tasks can lead employees to use unnatural standing positions.



Stephen Pheasent (1996) defined good posture of the body in which the human body is standing, sitting or lying upright against gravity. Good posture involves training the human body to stand, walk, sit and lie in positions where, during movement or weight-bearing activities, the least strain is placed on supporting muscles and ligaments. Muscular pain disorder (MSD) such as backache, pain in the shoulder, neck pain can be prevented if a person applies good and healthy posture in their daily lives.

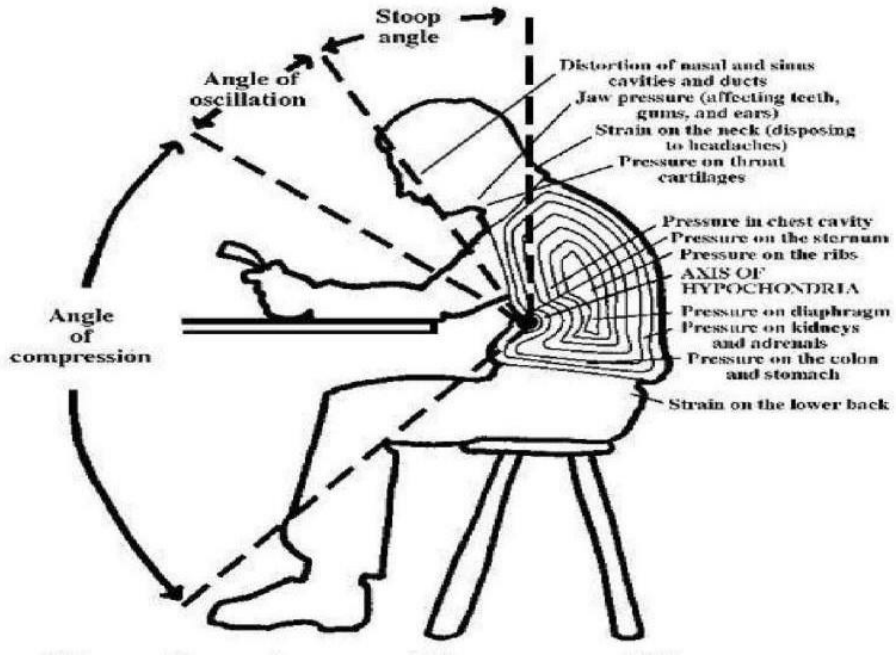



**Figure 2.3**: Body Posture (Source: The posture theory diagram, 2004)

### 2.2.1 Neutral Body Posture Working

Stephen Pheasent (2006) illustrates that each body joint usually focuses on movement and movement. Working in a neutral position with the body means that the normal, relaxed, comfortable situation does not distort any bent, twisted or otherwise distorted body parts. Awkward posture refers to positions of the body that differ significantly from the neutral position in the course of the work. Muscles work less effectively to accomplish the task with more strength and power. In these typical positions works a typical contributing variable or musculoskeletal disorder (Hsaio Keyserling et al., 1991). Working in a neutral position with your body reduces stress and stress on your muscles, tendons and skeletal system and reduces your risk of developing a musculoskeletal disorder (MSD). For particular body segments this means that a neutral posture conforms to the following guidelines:

**Table 2.1**: Musculoskeletal Body Parts (Source: Alan Hedge, 2016)

| Body part | Description |
|---|---|
| Neck | The neck is evenly balanced and aligned with the top of the spine and does not twist or bend, with a low forward or backward extension. |
| Back | The whole spine is upright in normal S shape, with no part of the spine bent awkwardly and no segment bent or twisted vertically. If the S-shaped spine but recline posture, this should be supported by an appropriate back support such as an ergonomic rear chair. |
| Shoulders | The shoulders are symmetrical and relaxed; no raising, shaking or twisting of a shoulder is necessary. |
| Upper arms | The upper arms are relaxed as close as possible to the vertical by a minimum or no removal on the body side, with a minimal forward expansion. |
| Wrist/ Hand | The hands are straight, not laterally bent, stretched to the bottom or twisted to the tips of pronation and supination. |
| Ankles/Feet | The feet may be flat on the ground below the lower legs, or if the legs and feet are stretched out, the feet should be on the incline foot support. |

Awkward posture frequently focuses on the spine, causing muscular fatigue and torment. The main function of a neutral posture is to keep the corpse upright and resist gravity. Excessive stress and weight can lead to great pain or discomfort on the muscles and joints. Extreme and unstable postures have been associated with musculoskeletal inconvenience and reduced back damage in working conditions.

## 2.3 Studio and Furniture Design

The type of communication can be supported or encouraged by a physical environment of a studio or classroom, so the tutor wants to learn. The ability to "make eye-contact" is, and is particularly important, the key to establishing communication between a group and the tutor. The layout and furniture of the design studio (such as desks, tables, etc.) is needed to motivate and stimulate the students. Group seating arrangements are also useful for revision classes, organizing tables where four or five students can sit is helpful for small group work sessions, promoting simple group starting training from the beginning of the session. It supports conversation and exchange within the small groups with the tutor (Sue Clabaugh, 2004).



To achieve optimal fitness between the studio furniture and the pupils, the furniture should be designed according to the psychophysical characteristics of the users as well as the specifications of the educational environment. The furniture of the classroom and studio must be both flexible and ergonomic (K Laxminarayana Rao, 2000). Ergonomic furniture like chairs, desks and keyboards are focused on supporting individually as they work. When people work on equipment that worsens their posture, they may experience a reduction in pain. Ergonomic furniture works to fix individual posture, adjust the spine, avoid arthritis, and reduce the number of work-related injuries in general.

Sue Clabaugh, (2004) stated using proper architectural and lighting elements, the focus is achieved. Higher furniture allows people to move much more freely and benefit from a variety of working postures. Several scientific studies have documented the beneficial results of high Scandinavian furniture on individuals ' postures and comfort, the results of which were generally distributed in ergonomics. It is important to have the correct height of the furniture; the edge of the desk is 2–4 centimeters above the knee with buttocks and the front of the chair.

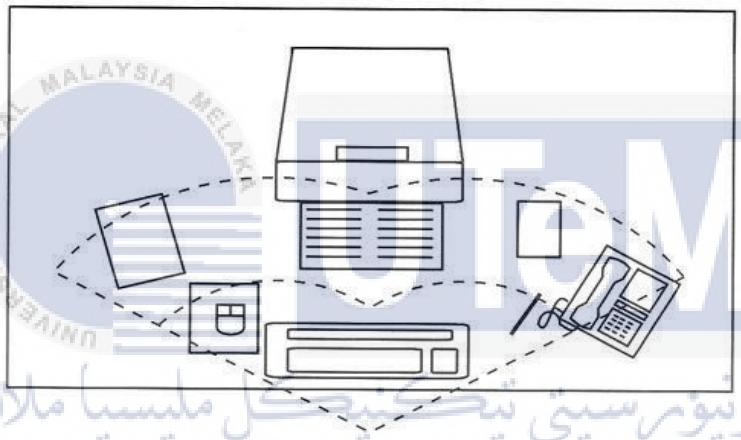


**Figure 2.4**: Office Ergonomics (Source: Wayne's Ed, 2016)

## 2.4 Ergonomically Designed Workstation Improve Productivity

Proper ergonomics play a significant role in supporting comfort in the workplace and helping to minimize unnecessary stress on the body. In order to better support productivity in the workplace, the office furniture should consider ergonomics in the design. Office workers should sit with straight, inline, and parallel hands, wrists, and forearms. The head should be level, facing forward with no left or right turn, and generally aligned with the trunk. An ergonomic seating option can help minimize injury, avoid distractions and make the workplace more productive (Hsaio Keyserling et al., 1991).

Individuals with ergonomic workstations are concerned and their productivity can be increased. There is more energy and more capacity to work for individuals comfortable. In industries where workers have to perform demanding physical tasks, ergonomic workstations often lead to fewer errors, not only do individuals concentrate better when they are not distracted by discomfort.

Sue Clabaugh, (2004) illustrates that the ergonomic equipment often makes an individual's work easier because it reduces repetitive motions and optimizes posture. Ergonomic keyboards can help with faster types and lower breaks, ergonomic cleaning technologies can clean large areas with less passes and frequently without bending, and computer monitoring designed to reduce the eye stress allows people to focus on their screens for more time without headaches.

## 2.5 Chair Classification and Characteristics

Arijit K. Sengupta (1996) stated that different working conditions should fit various categories of chairs in order to meet and comfort the chair's demands. There are in general three categories of chairs, which can be classified as working chairs, resting chairs and special chairs. The first is the work chair, which is suitable for work or other workplace when the operation in sitting position is necessary. The student must bend his upper body at this seat to reach the desk leading to his hunch back and without a doubt affect the health of the student.

The second type is called the resting chair, which is suitable for all vehicle types, aircraft, buses, trains, ships, etc. First of all, it is necessary to design this type of chair for comfort. The third category is special chair which it suitable for a particular condition and provides temporary assistance to people with disabilities. Ergonomic chairs are designed to

help people sit comfortably while doing their work for long periods of time. They are more adjustable than standard office chairs and enable individuals to adjust their own body fit or seating preferences Underwood, D., & Sims, R. (2019). While these chairs can improve productivity and job satisfaction, they will also reduce the risk of musculoskeletal injuries such as back pain, shoulder ache, neck pain and other musculoskeletal disorder (MSD) related problems.

There are five reasons why ergonomic chairs reduce pain in the back, including sitting height, seat depth, sitting width, chair back and chair arm. The chair should be designed for comfort in according with physiology, so chair design should include the following elements:

**Table 2.2**: Chair Design Elements (Source: Underwood, D., & Sims, R. 2019)

| Chair Design Elements | Description |
|---|---|
| Seat Height | The seat designed too high will strain the muscles of the legs and leave them resist and sore. The feet will lose contact with the ground if the seat height is too high, and the muscles behind the seat may also be hurt. Chairs that adjust vertically between 40 cm and 64 cm are thought to be the most ergonomic because it does not put any pressure on your knees. |
| Seat depth | The depth of the seat is a width from front to back to ensure that all buttocks are supported. The front of the seat should not lengthen too much to the calf, so that the size of the seat can be about 450 mm. |

| | |
|---|---|
| Seat Width | The seat width should hold the whole buttocks and it is easy to adjust the sitting posture. As shoulders, the chairs that connect with each other are designed to the width. |
| Chair Back | Chair back is a key ergonomic element in chair design, which is important for sitting posture and normal spine in shape and degrees. By simply filling the gap between the lumbar spine and the seat, a lumbar back support encourages good posture, supporting the natural inward curve of the lower back. |
| Chair Arms | Armrests, if the arms rest on the armrests, will support part of the body's weight through the arms. Armrests also have the function of facilitating the entrance and exit of the chair. Armrests should support the forearm instead of the elbow's sensitive area. |



## 2.6 Facility Design Elements

**Doors**

Sue Clabaugh, (2004) stated that for individuals with limited abdominal versatility, at least one set area approach arrangement should be monitored by both a high about 1 m above the Finished floor and approximately 180 cm above the finished floor. In some cases, internal doors can also be controlled when the entrance pressure exceeds 8.5 N. Door layoffs can sometimes be adjusted to reduce the opening pressure of the door The doors should be fitted with hardware resulting in a slow and quiet closure when fully closed to a tight sound seal. The doors should be able to stand open during class change to enable traffic flow.

**Accessible Routes and Fire Safety**

Accessible routes must connect accessible buildings or facilities in the building or facility with all available spaces and features. Accessible routes should also serve as an emergency exit or connect to an accessible rescue area. (Rescue areas in buildings with a supervised automatic sprinkler system are not required). Each rescue assistance area should be marked with an appropriate sign and should contain a two-way communication method. Rescue areas should be located in an exit area, protected from smoke and fire. Where the lifetime safety codes require audible alarms, visible alarms must be provided which indicate the same areas to be reported (K Laxminarayana Rao, 2000).

**Lighting**

Due to increased media use and innovation in classrooms, it is easier than ever to compare the design of simple, customized illumination frames. It is necessary to plan and design lighting in various ways. All training areas should have different lighting options, from comfortable reading to viewing the display screen. An effective classroom lighting scheme will use any available natural light, with artificial light being added where necessary. Natural light can provide students, teachers and administrators with physical and physiological benefits. The health, concentration and even test scores of pupils are shown to benefit from natural light. In effective classroom design, lighting is an important consideration.

**Projection Screens**

The requirement for numerous projection screens in lessons or studios is increased as the use of technology in education grows. Students complain that they have nearly no space in the single standard focus on the front of the room. A second screen cannot be

mounted in small rooms. In these instances, the screen on the other side is best mounted to maximize board space. These options remove delays in improving and reducing screen and mechanical problems with the electric screen. In smaller rooms, manual displays can be satisfactory, but large rooms prefer small-voltage electric displays (K Laxminarayana Rao, 2000).

## 2.7 General Purpose of Classroom

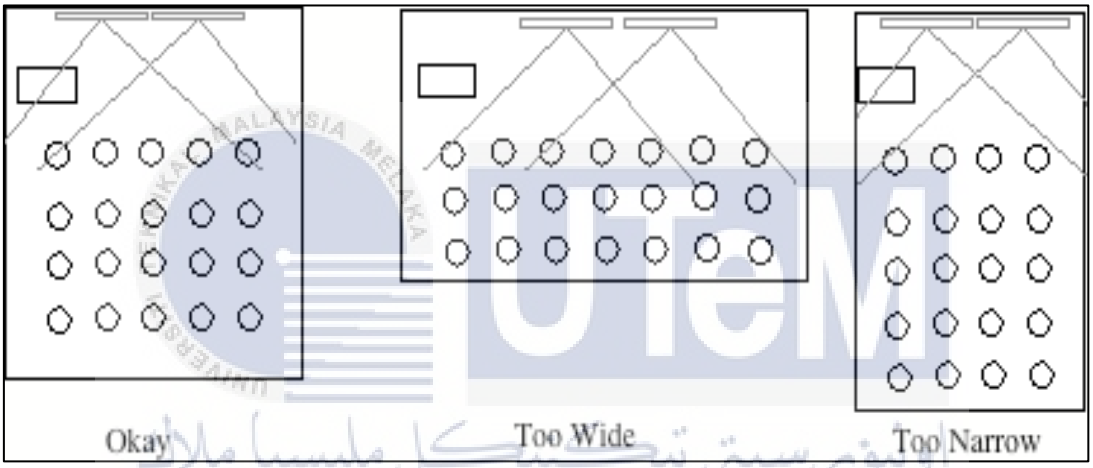



**Figure 2.5**: Classroom Layout (Source: Journal of Adolescent Health,1999)



Based from the article stated in Adolescent Health (1999), classrooms should be designed to provide good viewing angles for all students. Every student needs to have comfortable and adequate spaces in order to increase their productivity and performances. Rooms that are either too large or too small create wasteful space for the projected materials and the screen board and/or unacceptable viewing angles. There should be no obstacles in the classroom, such as columns or posts. No barriers should be made into the room behind the instructor's area at the front wall so that a cracking board can be installed throughout the entire instructor's area.

## 2.8 Rapid Upper Limb Assessment (RULA)

Dockrell, S et al., 2012 stated that rapid Upper Limb Assessment (RULA) shows a way of observing subjective posture analysis focusing on the upper body and also include the lower body. It uses a number of illustrations of various postures, and the most frequently observed position is assigned a numerical scoring. RULA was developed in the context of repetitive motion and strength for an adult's exposure to risk factors for work-related upper extremity disorders. It was designed quickly and with minimal changes in equipment or the working environment and minimal interference in observed environments. **Table 2.3** shows the steps taken to access a workplace using Rapid Upper Limb Assessment.

**Table 2.3**: RULA Steps to Access Working Posture (Souce: Dockrell, S et al., 2012)

| Step | Description |
|---|---|
| 1 | **Observing and selecting the posture to access**<br>A RULA evaluation is a moment in the work cycle and it is important to observe the positions taken during the tasks before selecting the evaluation position. The longest posture or what seems to be the worst posture can be selected depending on the type of study. In some cases, it may be more appropriate to conduct an evaluation at regular intervals when the work cycle is long, or the postures are varied. It will be evident that the amount of time spent in the different positions can be assessed if evaluations are carried out at certain intervals during the working period. |

| | |
|---|---|
| 2 | **Scoring and recording the posture**<br><br>Decide whether the left, right or upper arms should be evaluated. Use CATIA software to score the posture of each body part. Review the scoring and make any adjustments if necessary. Select the button for calculation. |
| 3 | **Action level**<br><br>The final score can be compared to the Action Level List, but it should be remembered that as the human body is a complex and adaptive system, it provides a guide for further action. The actions lead in most cases to a more detailed investigation to ensure that this guide is used as an aid in effective and effective control of any identified risks. |

## 2.9 Ergonomics Risk Factors

Fernandes, G (2018) stated that disorders of the musculoskeletal system are a major cause of absence from work. Considerable costs resulting from musculoskeletal disorders for the public health system. Different regions of the body and work may be associated with specific musculoskeletal system disorders. Upper limb disorders (fingers, hands, wrists, arms, elbows, shoulders, neck) may result from repetitive or long-lasting static force exertion or may be intensified. A wide range of working conditions, including lighting, noise, temperature, vibration, heavy lifting, repeating movement, the design of the workstation, machine design, design of bar stools and footwear. These factors can result in injuries or related problems involving tendons, muscles, or nerves that in most problems can cause musculoskeletal disorders (MSD).

Soft tissue (muscles, tendons, ligaments, joints, and cartilage) and nervous system injuries and disorders are MSD or musculoskeletal disorders. Almost all of the tissues, including nerves and tendons, may be affected and the arms and back are involved mostly. The increasing number of injuries caused by repetitive motion, excessive force and awkward postures; ergonomics has become a critical factor in workplace safety. Risk and risk factors are common concepts used in safety and ergonomics literature. Risk is often defined as the number of injuries or accidents resulting from an exposure. Risk factors are defined as actions or conditions which increase the probability of musculoskeletal system injury. In many occupations and work settings, applied literature on ergonomics recognizes small number of common risks. Defining the relationship between exposure to risk factors and the level of risk of musculoskeletal injury is not easy (Fernandes, G ,2018).

Physical risk factors are important first-line risk factors, there are other possible factors such as organizational and psychosocial factors that can cause a disorder or influence the effect of physical risk factors indirectly. Ergonomics Risk Factors (ERF) are situations that may or may not be harmful to the health and well-being of workers or users at work, either intentionally or unintentionally. Understanding and awareness of the negative aspects of ERF is critical and essential in order to take countermeasures before finding solutions to the problems. The ergonomics risk factors (ERF) discussed above are listed below:



**i. Repetition**

The repeat rate is the average number of motions or exercise performed by connecting the joint or body or by performing similar movements on the same body part in a unit of time and with little rest or recovery. Repetition consists of a task that has a low chance of rest or recovery and uses the same muscles time and again (Fernandes, G, 2018).

**ii. Force**

Fernandes, G (2018) illustrates that force is the mechanical or physical effort to achieve a specific exercise or movement. Force can be defined as the amount of physical effort required for performing a task (such as lifting) or controlling equipment or tools. The force a worker exerts on an object is a primary risk factor. It is possible to overload muscles and tendons when applying a strong force against an object. For long periods of time, holding a lighter object (such as a mouse) may also expose workers to MSI risk. Three kinds of activity, such as lifting, reducing or carrying power, involve pushing or pulling and grip, are necessary. This means that force is a person's physical effort to perform a task or keep control of tools or equipment.

**iii. Awkward Posture**

Awkward posture refers to body positions that significantly change the body position from the neutral position while carrying out work activities. When a body part is in a painful position, the bones, muscles and tendons are not naturally aligned to one another. The risk of musculoskeletal injuries is increased while maintaining an uncomfortable posture (Nico J. Dellman, 2004). Injury risks increase when a person in a certain posture is required to perform tasks outside their neutral range with segments of the body. Awkward position consists of twisting, bending, squatting, twisting, working with overhead hands and arms or holding fixed positions. The upper arm and the shoulder area of the neutral position are relaxed on the same plane with the arms at its side. When the arms are removed from the body, overly extended shoulder joints put them on the end of their normal range of motion, require increased muscle strength and increase the risk of injury.

### iv. Vibration

Stephen Pheasent (2006) define vibration as a body makes a fixed point of every movement. This movement can either be regular or random at the end of a spring, such as a weight movement. Vibrations have the result that high vibration levels and the breakdown of body tissue are affected, such as body organ damage due to either a continuous resonance or high-energy vibrations absorption. The result is relatively low frequencies. Hand vibration can cause hand / finger vascular failure (Raynaud's disease or vibration of the white finger). Raynaud's illness is a medical condition in which, in setting certain triggers such as cold weather, arterial spasm creates episodes of decreased blood flow. If patients with this disorder receive medication with vasoactive characteristics, they are at danger of negative responses Kim, I., Lindeman, K., & Masear, C. (2018)

### v. Contact Stress

Fernández, (2019) defined that contact stress is defined as the break or the injury when hard, sharp objects, appliances or tools are seized. When working with forearms or wrists against the edge of a desk or work counter, contact stresses are encountered. Local stress is associated with the skin when contact is made with a hard or sharp object. Pressure can harm the nerves and tissues of the skin. The effects of local contact stress can become worse when the hard object comes into contact with an area without much protective tissue, such as the wrist, palm or finger, and also when pressure is applied or maintained over and over time. When a tendon, nerve, or blood vessel is stretched or bent around a bone or tendon, internal stress happens. External contact stress happens when part of body pushes against a workstation element, such as the top desk or chair seat pan.

## 2.10 Summary of Chapter 2

Literature review is a scientific findings and contributions from theoretical and methodology to a specific topic. A literature review discusses published information in a particular subject area and sometimes information in a particular subject area within a certain period of time. The review of literature may also include the preparation of a thesis, thesis or journal article in the work of both graduate and postgraduate students. Also, literature reviews are common in a research proposal and are always used by the student.

This chapter mostly explains the ergonomics principle, the human body posture, and the characteristics of the design studio elements. This chapter basically illustrates the importance of ergonomics assessment that aimed at improving workplaces and environment to minimize the risk of injury or harm. In the next chapter, the methodology will be discussed. The methodology will include the selected approach to project development as it contributes with the progress plans and requirements to the completion of the project.

# CHAPTER 3

# METHODOLOGY

## 3.1 Overview

They are various types of activities which the designer can use in the overall process of design. The Product Design Specification (PDS) is the well-known strategy for product design selection. The methodology is required to produce a systematic and orderly research plan. In addition, the help of the Flow Chart and the Gantt Chart also helps smooth out the research planned. This chapter explains the overview progress on structuring the conceptual design starting from planning, information gathering, design process, benchmarking of existing design until Quality Functional Deployment and House of Quality.



## 3.2 Planning

### 3.2.1 Gantt Chart

The PSM 1 and PSM 2 Gantt chart is shown in **Table 3.1**. A Gantt diagram is a diagram usually used for project management. On the left of the diagram is a list of exercises and the appropriate time scale is shown at the top. The position and length of the bar show the end of the activity date or week. The bar is represented for each activity. The job required for this project is listed sequentially on a vertical axis, and in the horizontal axis of this Gantt diagram, the estimated time for the completion is shown.

**Table 3.1**: Gantt Chart for PSM 1 & 2

| GANTT CHART PSM 1 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity | Week | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Selection of Title | | | | | | | | | | | | | | | |
| Proposal Writing | | | | | | | | | | | | | | | |
| Literature Review | | | | | | | | | | | | | | | |
| Conceptual Design | | | | | | | | | | | | | | | |
| Selection of Conceptual Design | | | | | | | | | | | | | | | |
| Structural Requirement | | | | | | | | | | | | | | | |
| Material Characteristic & Type Selection | | | | | | | | | | | | | | | |
| Report Writing | | | | | | | | | | | | | | | |

| GANTT CHART PSM 2 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity | Week | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Detail Design | | | | | | | | | | | | | | | |
| Structure Analysis | | | | | | | | | | | | | | | |
| Justification on Design | | | | | | | | | | | | | | | |
| Final Design | | | | | | | | | | | | | | | |
| Report Writing | | | | | | | | | | | | | | | |
| Seminar | | | | | | | | | | | | | | | |

### 3.2.2 Flow Chart

A flowchart can also be defined as a diagram representing an algorithm as a step-by-step approach for a task solution. A flowchart is a workflow or process diagram**. Figure 3.1** demonstrates the report flowchart beginning with the evaluation of the literature. The gathering of information about the issue declaration leads to the development of conceptual design. The result of conceptual design creation produces detailed design as well as structural analysis.

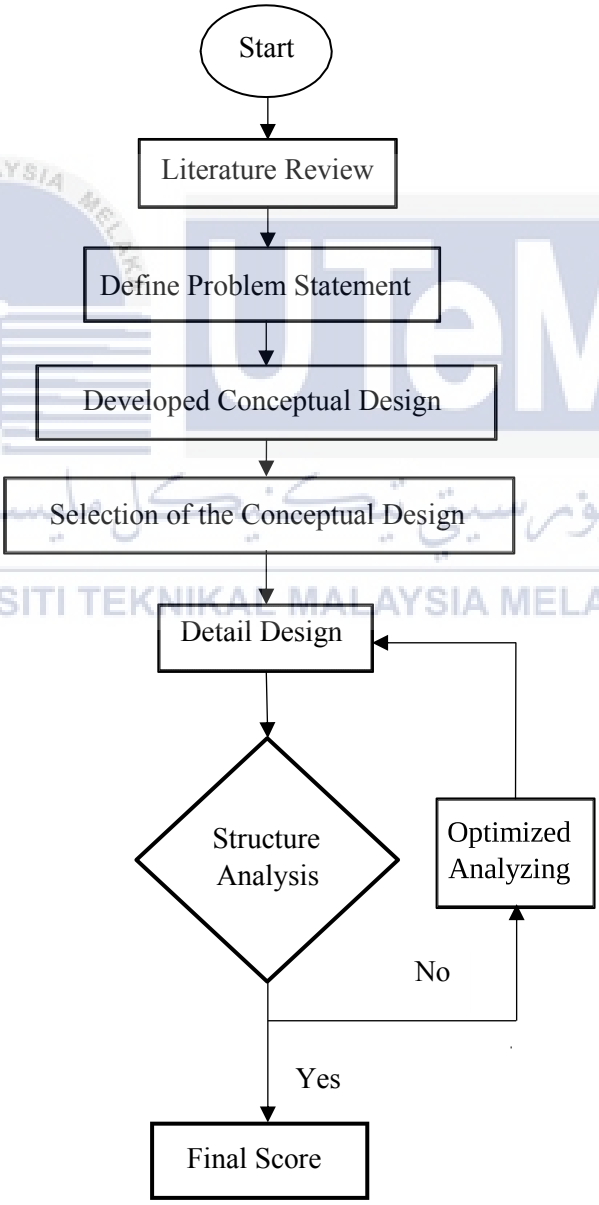



**Figure 3.1**: Flow Chart

## 3.3 Information Gathering

It is the customer's desires and wants to drive the development of the product or item not the vision of the engineer of what the customer should be looking for (Andress, J., & Linn, R, 2017). A research tool is a questionnaire comprising a number of questions (or various types of requests) to collect data from respondents. This is not always the case, despite the fact that the questionnaire is intended regularly for a statistical analysis of the answers. Questionnaires benefit from the fact that they are inexpensive, don't need as much effort from the questioner as verbal or telephone surveys and often have standardized responses that make it easy to compile data.

Customer surveys is a written questionnaire (google form) for this design studio ergonomics evaluation. The questionnaire is best used for publicly understood views on the redesign of existing products and new products. A survey is completed by providing each customer with mail, e-mail, phone or in person link to this questionnaire. Other regular reasons and explanations behind conducting a review include organizing issues and assessing whether a successful solution to a problem has been implemented. A survey should be possible via mail, e-mail, phone or person.



## 3.4 Design Process

The design process started by evaluating the existing studio design. The layout of the current Studio Reka Bentuk (SRBK) will act as a reference to other conceptional design. The measurement of the design studio capacity is considered and counted which is 7m x 14m for the width and length. After new layout of studio design was drawn using SketchUp software, ergonomics analysis will be applied to the workplace design during the movement of the individual at their workplace. The ergonomics analysis result will be collected and

discussed. House of Quality can also be used to determine which engineering characteristics should be treated as constraints for the design process and which should become decision criteria for selecting the best design concept.

For the conceptional design of this project, three concepts of ergonomics design studio have been analyzed by referring the existing studio design as a reference. The concepts are choose based on the engineering design method and the result of Weighted Decision Matrix and Pugh Selection Method. The highest criteria result will be chosen as the best concepts and selected as the conceptional design.

## 3.5 Benchmarking

Ren, P. (2019) defined that benchmarking is a process for measuring the operations of a product against the best product practices for both the industry and abroad. The layout of the studio is too compact from the existing design that is Studio Reka Bentuk Computer (SRBK). Because of the compact space, students find it difficult to move around. Also bad for the human musculoskeletal system is the workplace design. Position of the keyboard and mouse is not suitable for the student's comfort as they have to sit at their workplace for several hours.

Benchmarking is used to develop performance data that is needed to set the expected function for new products and classify market competition. To refer to the existing designs, product research is very important. Because they can be improved, the best ideas are often developed from existing designs, and lessons learned from previous errors or design errors. **Figure 3.2** shows the existing design of conceptual design which is Studio Reka Bentuk (SRBK). The exact layout of the design studio is 7m width 14m length.

**Figure 3.2**: Existing Design Conceptual Design

## 3.6 Quality Functional Deployment (QFD)



Quan Mao & Nan Li (2019) stated that QFD is a process and set of tools used to effectively characterize and convert customer demands into detailed engineering specifications and planned products that meet these requirements. QFD is used to convert customer requirements or customer voice into measurable design goals and drive them down from assembly level to subassembly, component and manufacturing process levels. The QFD methodology provides this movement with a characteristic set of frameworks. The importance is increased to obtain a relative weight contribution from the mathematical benchmark. **Table 3.2** portrays the customer needs and the important level of Quality Functional Deployment.

**Table 3.2**: Quality Functional Deployment

| Customer Needs | Important | Product Requirement |
|---|---|---|
| Safety | 5 | Higher security and safety product. |
| Comfortable | 5 | Good posture, less exertion, fewer motions |
| Costing | 4 | Low maintenance and services costs |
| User-friendly | 5 | Provide good user experience |
| Ergonomics | 5 | Improve workspaces and environments to minimize risk of getting injury or harm |
| Convenience | 4 | Ease customer need |
| Quality | 3 | Improvement in performance and features |

## 3.7 House of Quality

House of Quality is a diagram or chart used to describe the relationship between user requirements and capabilities. The "House Quality" is a key tool for the development of the management approach called quality function deployment (QFD) Kraslawski, A. (2017). The quality of the house is a functional plan and means of communication. Products with different problems and responsibilities can identify design requirements while referring to home grid evidence models.

There are few basic steps in building House of Quality which shown in **Figure 3.3**. The first step is identifying what customer wants and how the product will satisfy the customer. Next step is developing importance ratings. It refers to utilize the customer's importance ratings and weights from the connections in the grid to register importance ratings and evaluation. Lastly, determine the desirable technical attributes.

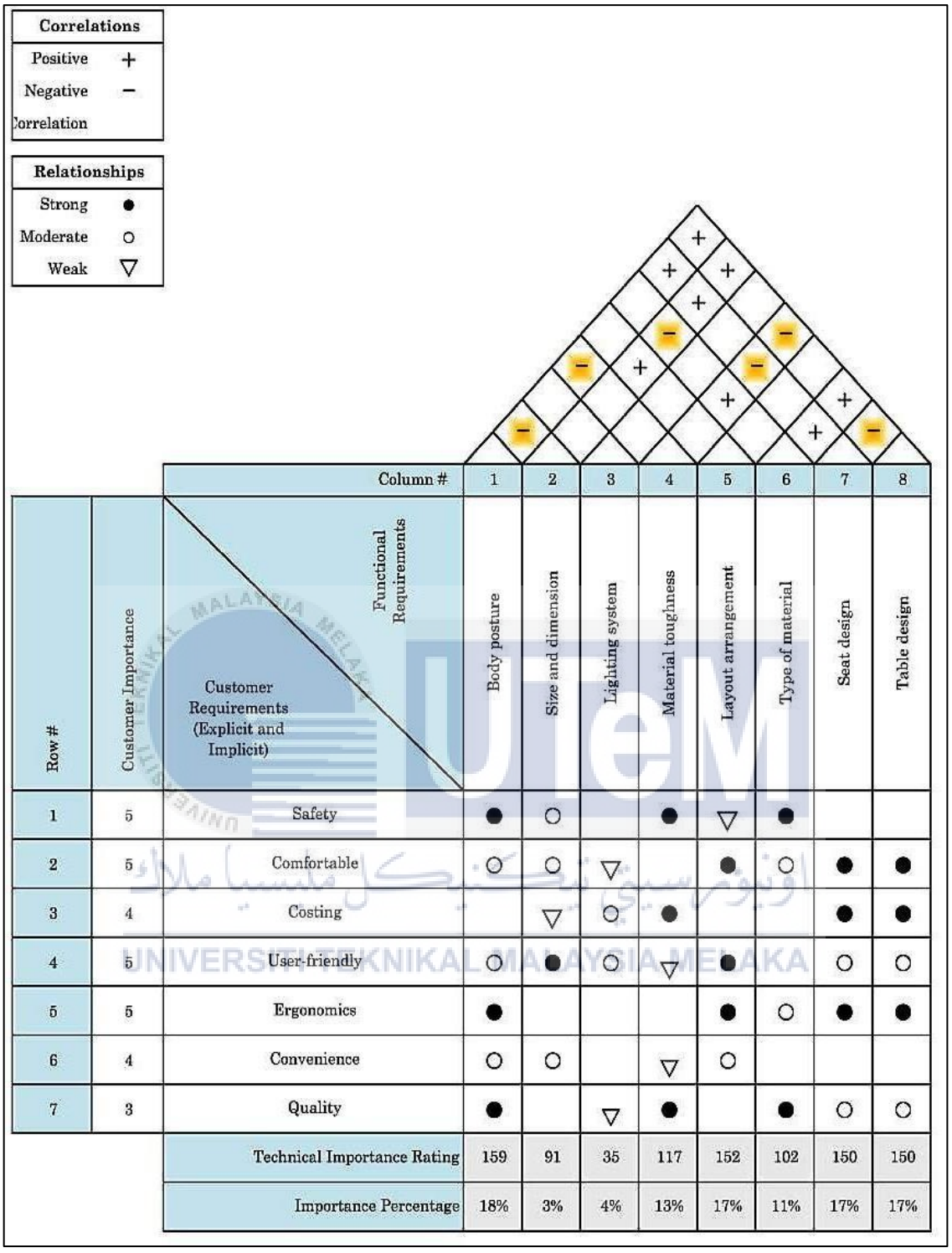



**Figure 3.3**: House of Quality

The ergonomics evaluation for design studio FKM shows seven customer requirements which is safety, comfortable, costing, user-friendly, ergonomics, convenience and quality. The rank order of engineering design specifications was determined based on customer desire and ranked according to technical importance rating.

Body posture has the highest value which is 159 out of 956 with 18% of importance rating. Body posture suits best with ergonomics design due to students have to seat at their workplace for several hours. Without good ergonomics posture, individual will have problem with their musculoskeletal system. Layout arrangement stated the second highest technical importance rating with 152 and round off to 17% importance rating. Layout design arrangement affect the student daily productivity.

Seat design and table design shows the same amount of technical importance rating which is 150 with round off to 17% rating. Students need to have a really proper table and seat design at their workplace because there is a lot of movement at the workplace compared other areas in the design studio. A good chair design promotes overall comfort and will increase the productivity if the student itself. Material toughness recorded the fourth highest place of technical importance rating which is 117 and 13% importance percentage. The toughness material is important because it gives safety to the consumers and customers.

The technical importance rating for type of material is 102 out of 956 rating with 11% of important percentage. One significant importance of material selection is it provides design flexibility for the producers. The sixth highest technical importance rating for size and dimension is 91 with 4% of importance percentage. Students more prefer larger space at their workplace because of the comfortability. Lastly lighting system recorded the lowest result of technical importance rating which is 35 out of 956 with 3% of importance percentage.

## 3.8 Summary of Chapter 3

This chapter illustrates the process used to collect information and data gathering for the purpose of creating the conceptual design. The methodology may include publication research, interviews, surveys and other research techniques, and could include both present and historical information. Six methods for implementing ergonomics analysis in the FKM design studio are identified in this study which is listed on the **Figure 3.4**. Systemic and orderly research plan must be produced using a research methodology method. Design system or design method can be all processes, technical assistance or planning tools. Furthermore, the help of the Flow Chart and the Gantt Chart also helps to smooth out the planned research. They are various types of activities that the designer can use in the overall design process.

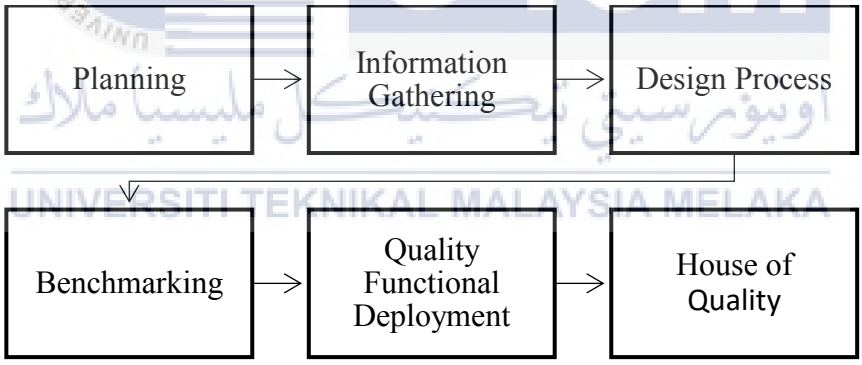



**Figure 3.4:** Methodology Progress

# CHAPTER 4

# CONCEPTUAL DESIGN

## 4.1 Introduction

Conceptual design is an early stage of the design process that articulates broad outlines of something's functions and shape. It covers the design, experience, processes, and strategies of interactions. It involves an understanding of human needs and how products, services and processes can be met. Concept sketches and models are the common objects of design. Chapter 4 describes the concept evaluation design starting from creating new product in the multi-phase process. Morphological chart is used to illustrate method and strategy for analytically and systematically generating ideas accurately.

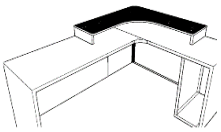
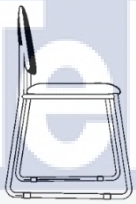
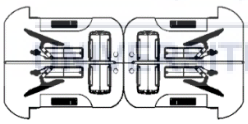
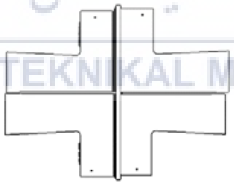
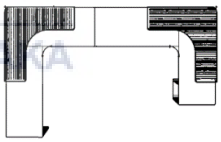


## 4.2 Morphological Chart

The morphological chart illustrates methods and strategies for precisely analytical and systemic generation of ideas. Depending on their abilities, possible components are recorded in a morphological chart. Functions are listed as the means by which they are listed in rows in columns and components. This led to a matrix of the functions and components. An idea comes through the careful selection and combination of a number of components. There are functions (listed in columns) and components (listed in rows) in a morphological chart. The parameters describe the features a product should have (characteristics) as shown in **Table 4.1**. The parameters indicate what the product is supposed to be as important to the

solution. The components are the means of achieving the functions (or features) of the product. For design studio FKM there a four conceptual design with each have different characteristic. Five concept that portrays in this morphological chart are table design, chair design, class layout and room capacity (Dragomir, M., Banyai, D, 2016).

**Table 4.1**: Morphological Chart

| Concept | Option 1 | Option 2 | Option 3 | Option 4 |
|---|---|---|---|---|
| Table Design |  |  |  |  |
| Chair Design |  |  |  | |
| Class Layout |  |  |  |  |
| Room Capacity | 10-20 | 20-30 | 30-40 | |
| Class Size | It can be neglected due to all class size follows the exact measurement of existing design studio FKM (SRBK) | | | |

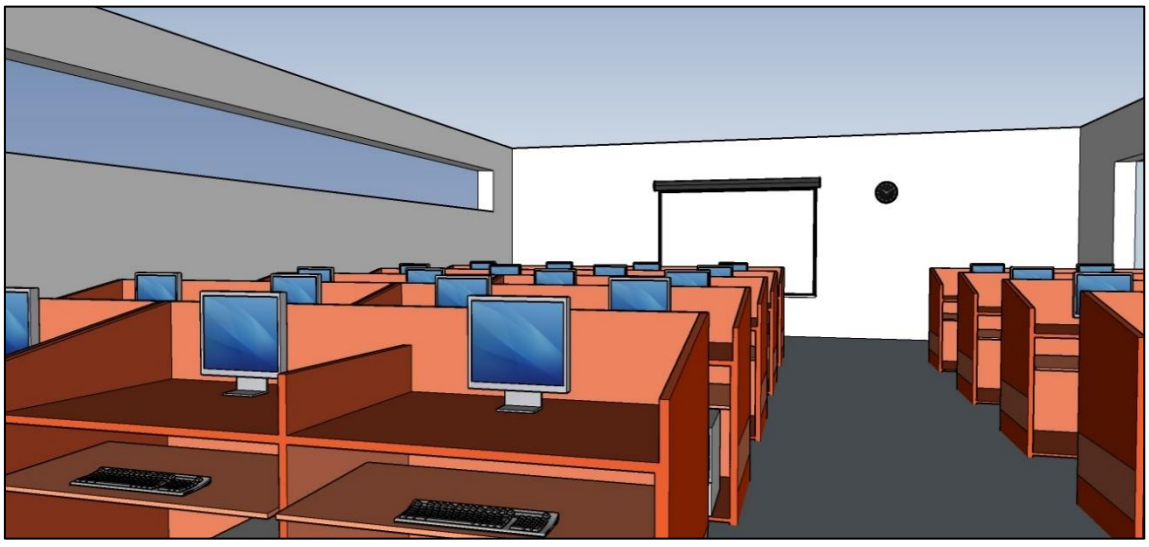
## 4.3 Importance of Conceptual Design

Conceptual design is important in building a strong user-centered basis for a successful user interface. A simple, defined conceptual design that represents the user interface clearly and accurately, allows users to get to know and use the product. The first step must be to design the concept, as the results of this step lead to further details in the design and engineering process.

## 4.4 Conceptual Design of Existing Design

**Figure 4.1** demonstrates the current design idea where it suits up to 30 learners. This class layout is systematically placed with normal class layout. The size of the class is 7 m wide and 14 m long. This concept design is implemented in multiple universities and schools. The disadvantage of this classroom is that owing to the bad chair and desk configuration, it may generate unproductive and fatigue students. This current design may leave the student feeling frustrated due to tight workspace and compact layout. The classroom arrangement makes it difficult for students to move around and interact with others.





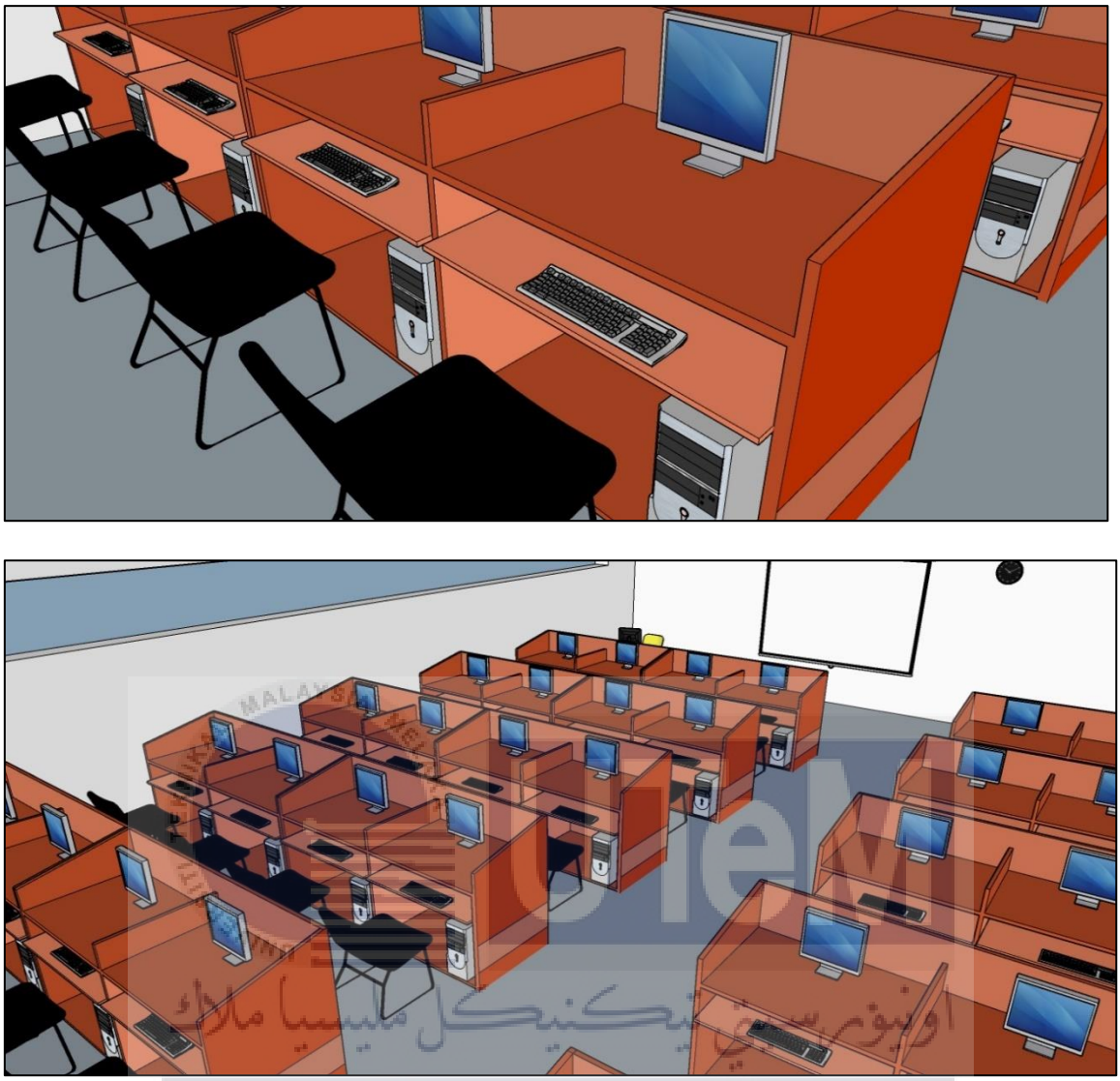


**Figure 4.1**: Existing Design Concept



## 4.5 Concept Generation

Concept Generation is a system that starts with the customer needs and objectives and produces a number of options for item planning that choose the final structure. The idea of the concept can be defined as "a description of the technology, work standards and form of the product." Conceptual design is important for building a solid and user-centric basis for a successful interface. A basic, well-defined conceptual design that is accurately presented in the user interface makes learning and using a product easier for people.

### 4.5.1 Concept 1

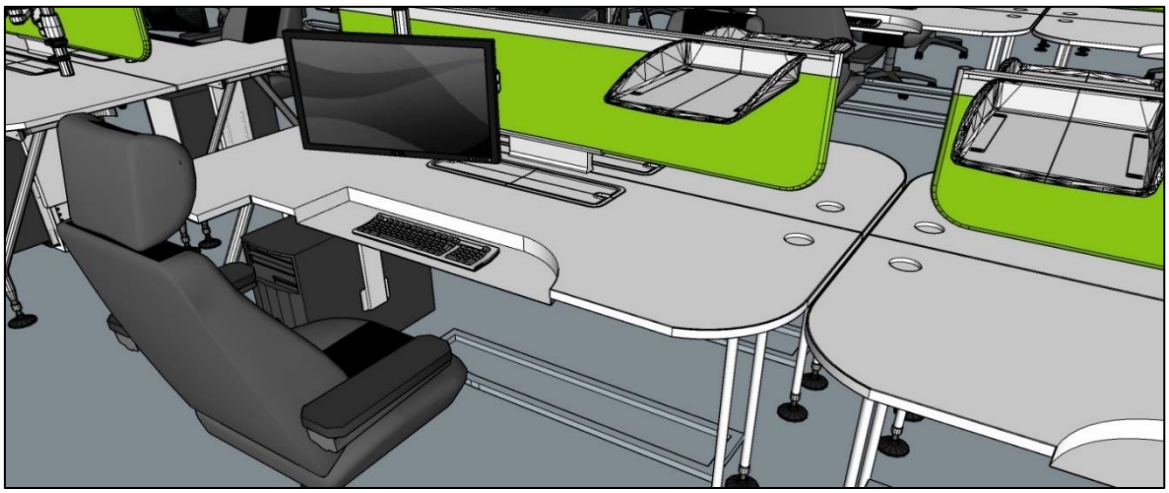


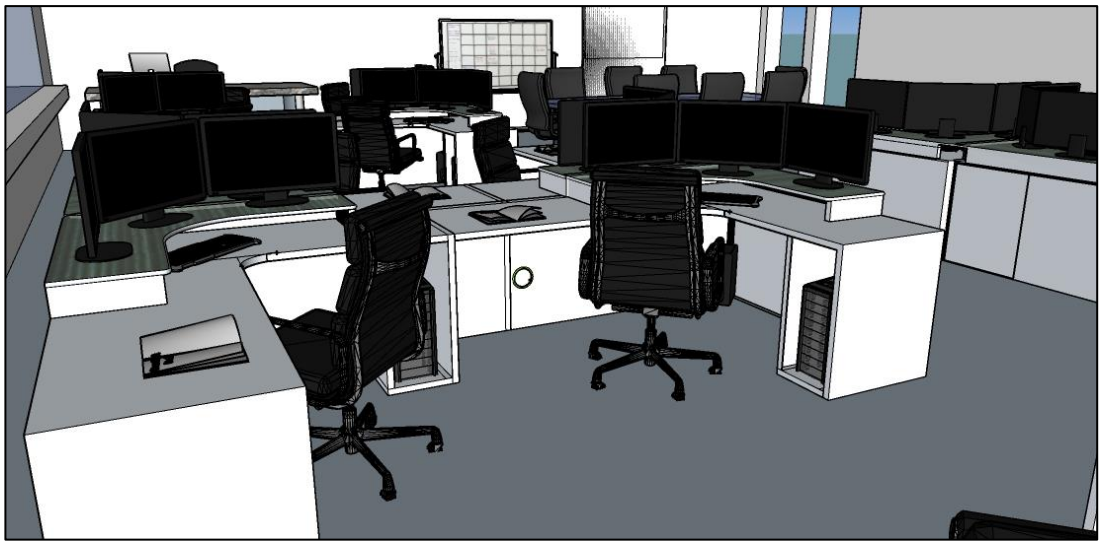


**Figure 4.2**: Concept Generation 1



This Concept Generation 1 (**Figure 4.2**) demonstrates the ergonomic design studio layout. Due to expanded workbenches, computer facilities and big presentation panels and screen, this concept design is appropriate for learners to create new products and objects. A total of 30 learners can fit into the design studio. The benefit of this idea is that each student has their own workspaces with appropriate posture when using computer equipment. This concept design will discourage learners from getting multiple muscle injuries such as backpain, neck pain, and lower body pain.

### 4.5.2 Concept 2



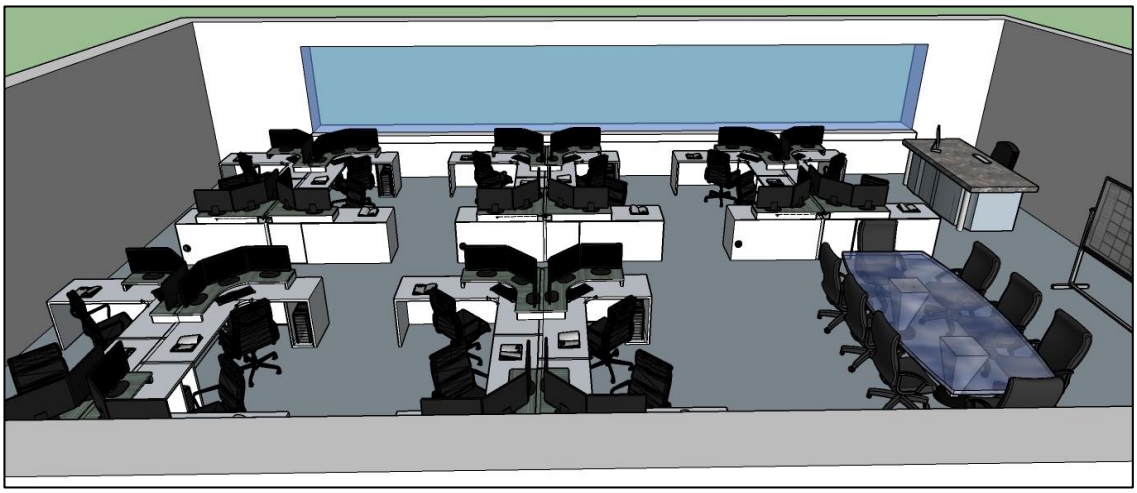
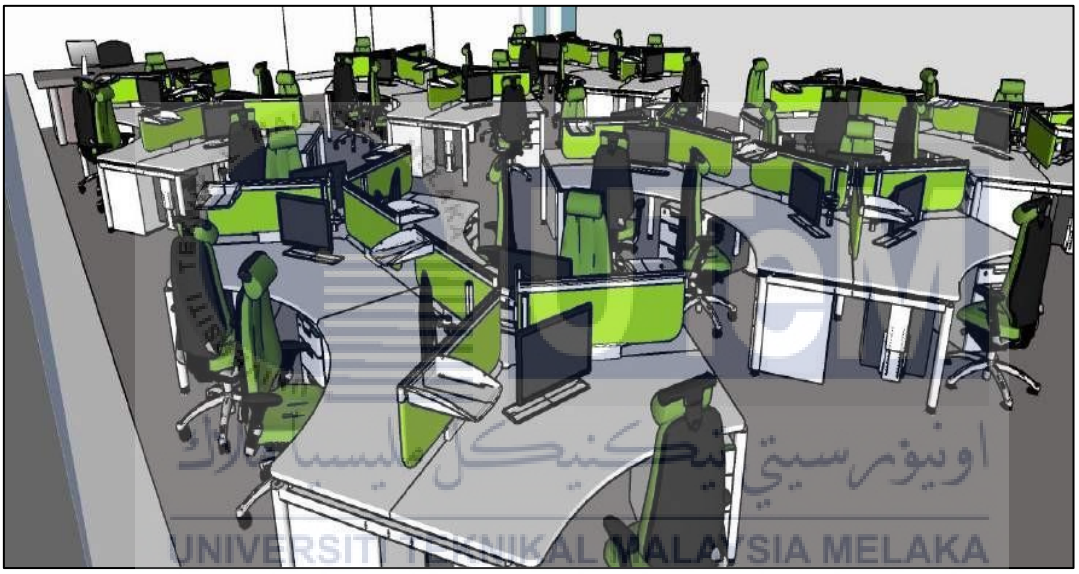
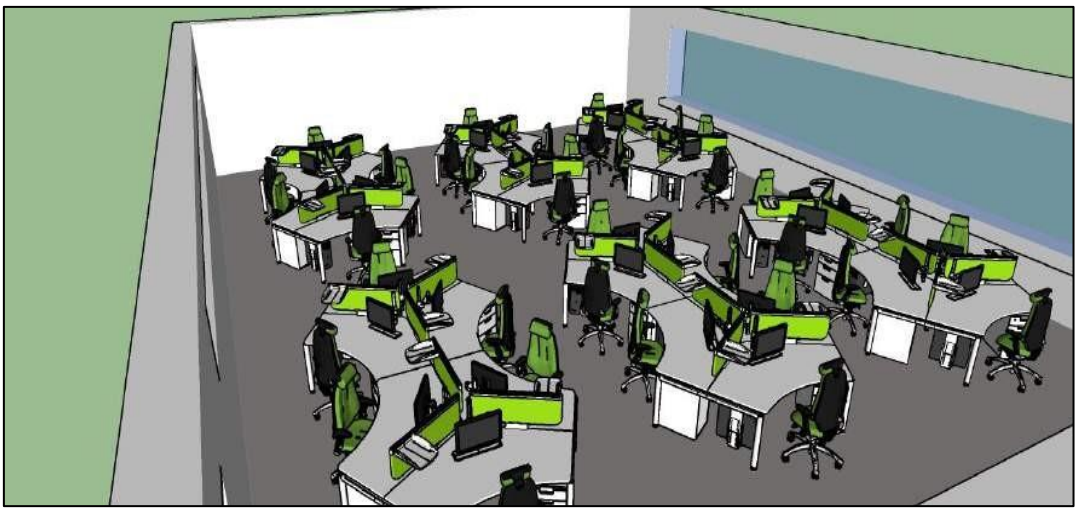


**Figure 4.3**: Concept Generation 2

From Concept Generation 2 (**Figure 4.3**), a total of 20 ergonomics chair and table is used. This concept generation is suitable for small amount of student capacity due to the studio layout. The advantage of this concept generation is all the tables and chair are placed systematically organized. The design studio layout makes it easier for the student to move around and also makes it easier to control the class by creating an open and friendly environment in the classroom.

### 4.5.3 Concept 3





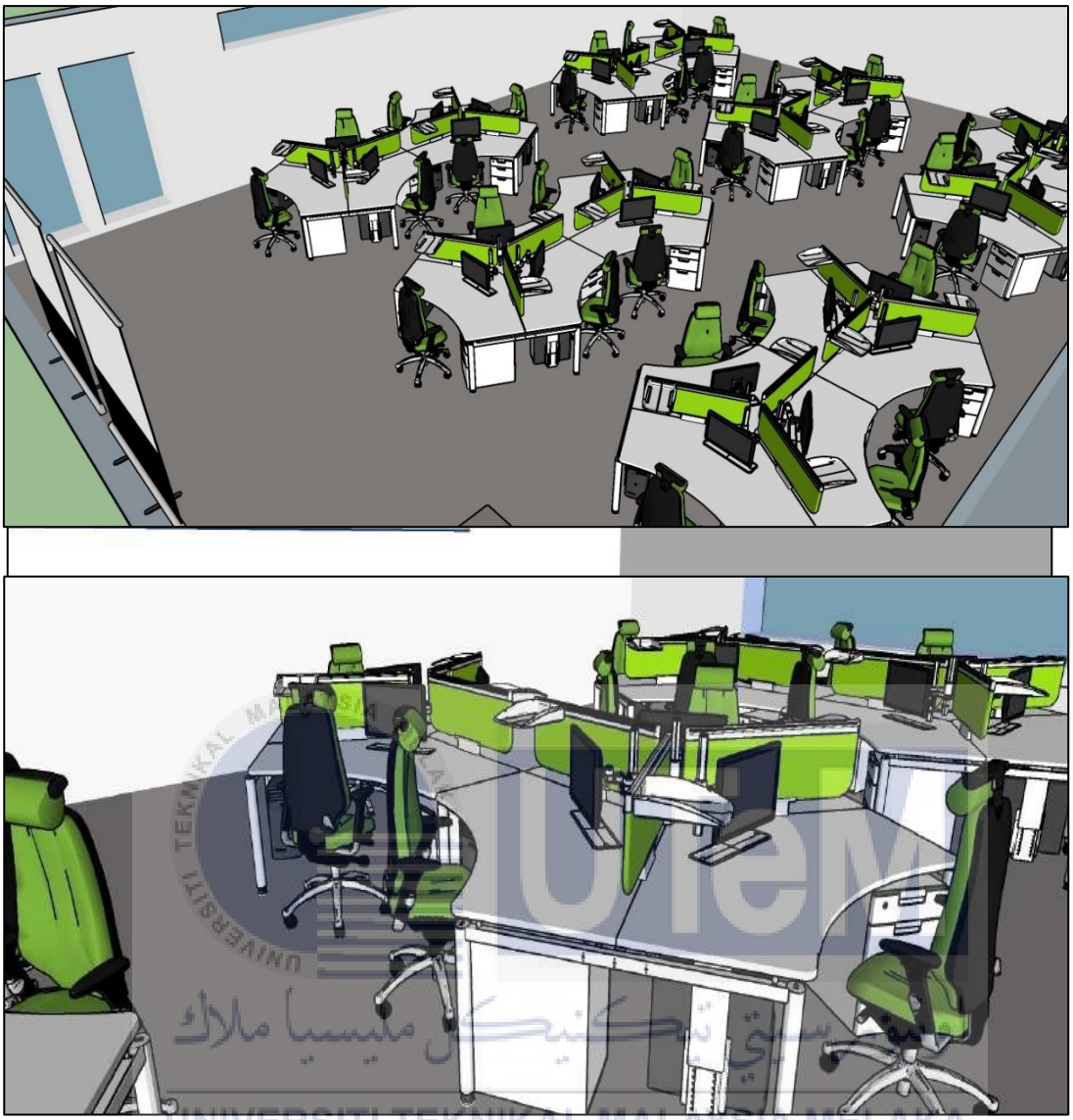
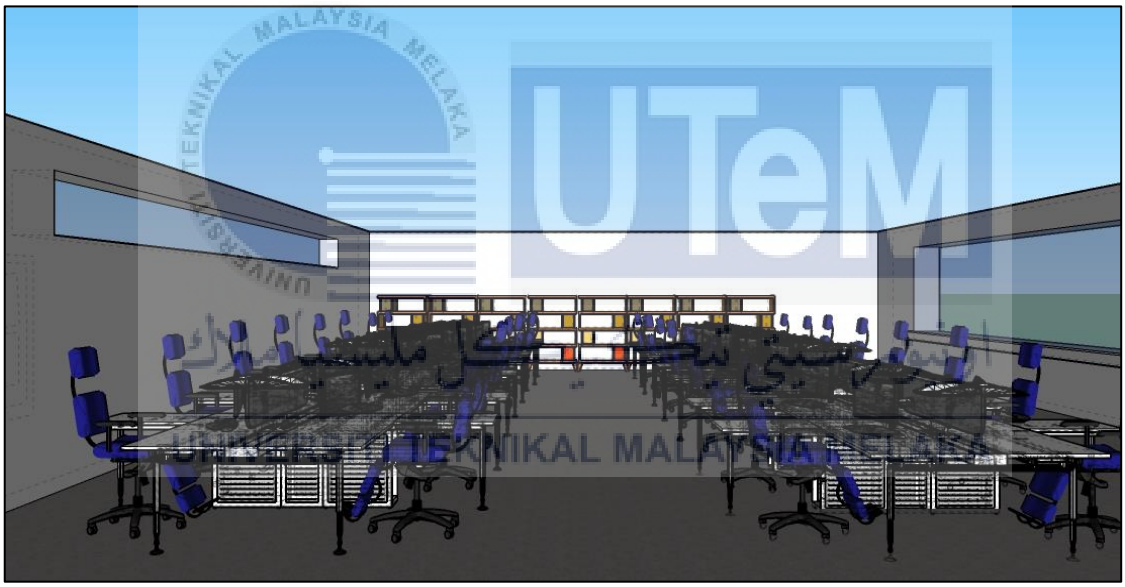


**Figure 4.4**: Concept Generation 3

A total of 36 ergonomic chair and table are used based on Concept Generation 3 (**Figure 4.4**). Because of the design studio layout, this concept generation is appropriate for big amounts of student ability. The outcome of this layout is that every student has space to using laptop, and the teacher can set up question and response session with the student rather than interactive conversation with the learners. This conceptual design will generate a comfortable atmosphere for the student and less stress will occur. The arrangement of the classroom makes it simpler for learners to move around and communicate with others.

### 4.5.4 Concept 4



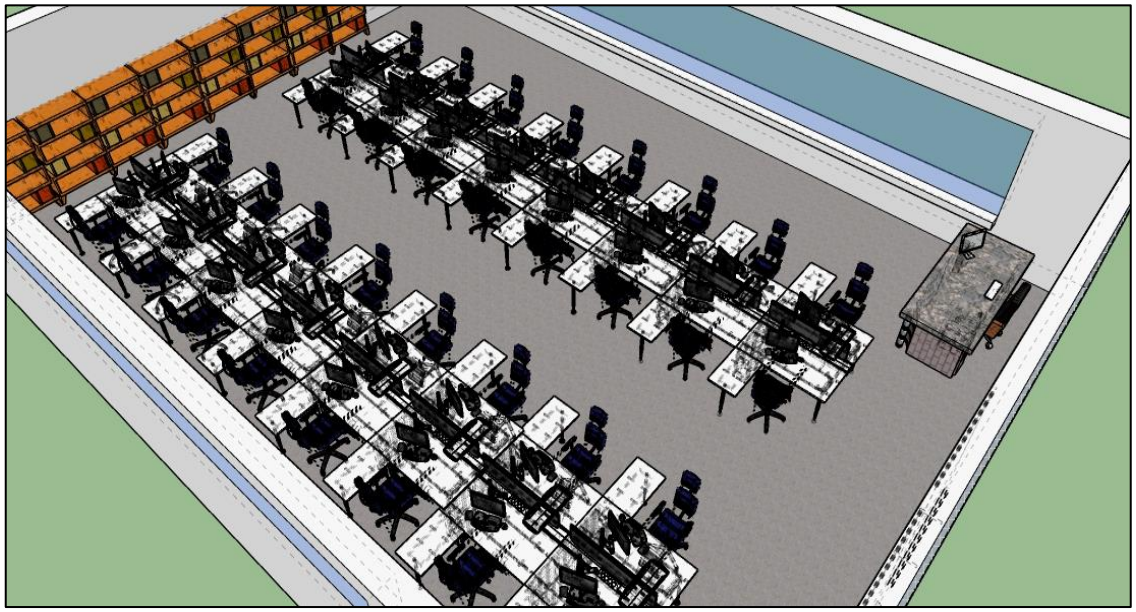


**Figure 4.5**: Concept Generation 4

The 4th concept (**Figure 4.5**) can be used to accommodate a total of 20 to 30 students. This layout is composed of 32 ergonomic chairs and table. Due to the design arrangement of the design studio, this concept generation is suited for average student capacity. Rows of rotary tables facing the front of a room and each person has the space to write or use a computer. The advantage of this design is that each student has a good front room view. The classroom arrangement makes it easier for the student to move.



## 4.6 Concept Evaluation

Concept evaluation is the method of assessing ideas in order to determine their comparative merits. This requires a ranking of criteria on which each idea is rated, a baseline design for comparisons and to be used, and a process for ranking ideas against those that are efficient concept assessment enables users choose the best among many ideas. It offers user with distinct techniques of measuring the notion of fitness on the basis of which it describes one specific idea according to our necessary criterion.

### 4.6.1 Pugh Selection Method

This is a method for selecting the concept using the Pugh matrix. It is carried out by setting up an evaluation team and a matrix of assessment criteria compared with other models as shown in **Table 4.2**. This method is useful in selecting the design based on the scoring for the best design. Below is the Pugh Matrix Chart which sets the reference point for the other conceptual design of all ergonomics studios that represent the existing design.

**Table 4.2**: Pugh Selection Method

| Selection Criteria | Concept | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Human Position | + | 0 | + | + | DATUM |
| Ease of Use | 0 | - | 0 | 0 | |
| Ease of Handling | + | 0 | 0 | 0 | |
| Layout Arrangement | 0 | 0 | + | - | |
| Material Comfort | + | + | - | + | |
| Studio Size and Dimension | 0 | 0 | 0 | 0 | |
| Simplicity | + | 0 | + | - | |
| Safe | 0 | 0 | 0 | 0 | |
| Material Durability | + | + | 0 | + | |
| Sum +'s | 5 | 2 | 3 | 3 | 0 |
| Sum 0's | 4 | 6 | 5 | 4 | 0 |
| Sum –'s | 0 | 1 | 1 | 2 | 0 |
| Net Score | 5 | 1 | 2 | 1 | 0 |
| Rank | 1 | 3 | 2 | 3 | 0 |

#### 4.6.1.1 Step in evaluating the characteristic and scoring result

i. Select or develop comparison criteria

- Create a set of requirements and goals for engineering. Examine the regulatory requirements to do so.

ii. Choose the options to compare

- Different ideas during concept production are the alternatives. All concepts are compared in similar language at the same level of generalization.

iii. Generate Scores

- This concept is used as a datum and all the others are compared to it according to each customer needs. The product must be assessed as better (+), the same (0), or worse (-) in every comparison. Alternatively, use +1, 0 and 0 for ratings when developing a matrix with a table like Excel.



iv. Calculate the overall result

- Four scores, plus values, minus scores, the total and the weighted total are generated.
- The total is the plus-score, the minus-score number.
- The total weighted is added up to the values by their respective weighting factors.
- In the decision-making process, the total should not be considered as absolute but as a direction alone.

v. Variations on scoring

- There are a number of differences in the scoring of Pugh. When too many concept designs with high evaluation are present, this variation measurement will be implemented to find the best concept design.

Therefore, based on example above, the higher scoring in Pugh Matrix chart are the concept generation 1 and 3.

### 4.6.2 Weighted Decision Matrix

A weighted decision matrix is a tool used to compare alternatives with multiple criteria of various importance levels. It can be used to classify all alternatives with a "fixed" reference, thus providing a partial order for the alternatives. WDMs are often used as a qualitative tool for assessing alternatives in design engineering.



**Table 4.3**: Weighted Decision Matrix Rating

| Rating | Value |
|---|---|
| Unsatisfactory | 0 |
| Just Tolerable | 1 |
| Adequate | 2 |
| Good | 3 |
| Very Good | 4 |

**Table 4.4**: Weighted Decision Matrix

| | | CONCEPT ALTERNATIVE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | CONCEPT 1 | | CONCEPT 2 | | CONCEPT 3 | | CONCEPT 4 | |
| CRITERIA | IMPORTANCE | RATING | WEIGHT RATING | RATING | WEIGHT RATING | RATING | WEIGHT RATING | RATING | WEIGHT RATING |
| Environmentally Friendly | 15 | 4 | 0.6 | 4 | 0.6 | 4 | 0.6 | 3 | 0.45 |
| Safety | 15 | 5 | 0.75 | 4 | 0.6 | 4 | 0.6 | 3 | 0.45 |
| Quality | 10 | 4 | 0.4 | 4 | 0.4 | 3 | 0.3 | 4 | 0.4 |
| Innovative | 25 | 5 | 1.25 | 3 | 0.75 | 5 | 1.0 | 2 | 0.5 |
| Ease Customer | 10 | 5 | 0.5 | 4 | 0.4 | 3 | 0.3 | 3 | 0.3 |
| Well Made | 15 | 4 | 0.6 | 4 | 0.6 | 4 | 0.6 | 3 | 0.45 |
| Affordable | 10 | 3 | 0.3 | 2 | 0.2 | 2 | 0.2 | 3 | 0.3 |
| | 100 | NA | 4.4 | NA | 2.95 | NA | 3.6 | NA | 2.85 |



In order to measure the concept design from the table above, a rating scale is provided where zero, means that in the final decision, the factor is unimportant, and which is unsatisfactory. There are seven criteria that are ecological (environmentally friendly), safety, quality, innovative, easy to use, well-constructing and affordable which are shown in **Table 4.4**. In terms of innovative criteria, weight is of the greatest importance at 25%, while three criteria have the lowest quality, cost-efficient and 10% user-friendly weight. Concept 1 is the highest value of customer requirements when comparing the entire concept design. The innovative design has the highest value of 1.25 based on the requirement.

## 4.7 Existing Design and Two Best Concepts

The two best concepts and existing designs have been selected and ready to move up to the next level following the previous step perfectly, according to the Pugh Selection Method and Weighted Decision Matrix. The next step is to use Rapid Upper Limb Assessment (RULA) in CATIA V5R21 software to design and analyze the details of the three concepts.

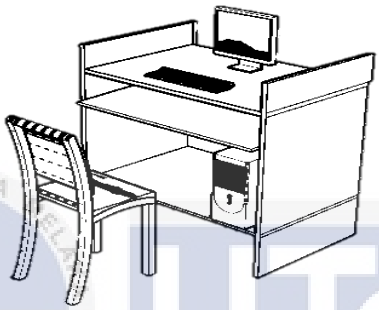


**Figure 4.6**: Existing Design Concept (Workplace)

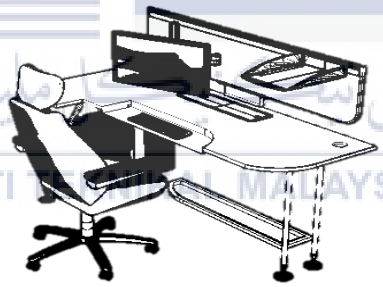


**Figure 4.7**: Concept Generation 1 (Workplace)

**Figure 4.8**: Concept Generation 3 (Workplace)

## 4.8 Summary of Chapter 4

Conceptual design is the first step in creating a new product in the multi-phase process. Before proceeding, it is important to come up with a general concept, whether it is a building, software application or gadget. The conceptual design phase follows the schematic design phase immediately. The morphological chart is used to illustrate method and strategy for analytically and systematically generating ideas accurately. To obtain the best new design concept, four design concepts are created. The analysis of the Pugh Selection Method and the Weighted Decision Matrix were done to analyze the best design concept to be chosen in this project to select the best design concept. Concept Generation 1 and Concept Generation 3 were used with existing design as a reference. In the next chapter, which is engineering analysis, all three designs are analyzed using ergonomics analyzes to determine their final score.

# CHAPTER 5

# ANALYSIS AND DISCUSSION

## 5.1 Introduction

The design process includes three methods, software analysis, analytical numerical data and manual calculation. In order to analyse human posture movement, the project used software analysis. The results of ergonomics analysis will be influenced by human posture, distance between the objects of the workspace and the posture where it lasted the most. The breakdown in its fundamental elements of an object, system, problem or issue may be described to reflect its fundamental characteristics and relationships with each other and with external elements. A thorough and varied analysis of a design before implementation often leads to increased safety and efficiency in the use of the product. The analysis shown in this chapter illustrates the best conceptual design with its highest ergonomics score value.



## 5.2 Analysis on Body Posture

To design the chair and table suitable for anthroponymy, analyses should be carried out on the body, including the position of the human sitting. Human beings are supported in sitting position by spine, buttocks, legs and feet (head added if the back is sufficiently high). Some of sample analysis that need to look throughout this analysis is pressure on spine, stress on haunch and legs.

### 5.2.1 A pressure on Spine

Nico J. Dellman (2004) shows that spine is in the central trunk and forms supporting body axis. It is separated by 20 vertebras (7 cervical vertebras, 12 thoracic vertebras, 5 lumbar vertebras and 5 rump bones) which are held together by ligaments. Comfortable chair means that the body's posture is the closest to its natural state. When the spinal column presents its natural curve, the lumbar lying on the side under relaxation is the natural waist state.

### 5.2.2 The Stress on Hunched and Leg

The weight of the legs and trunk is supported by the seat in the sitting posture, and the body weight is mostly supported by two small rounded protuberance under the pelvic. The stress that hucklebone protuberance undertake is the greatest and the stress gradually decrease when goes outboard, until the stress of thigh underside which connects with the edge of seat is the least. The protuberance of buttocks is the optimal position to undertake stress, the thigh should be avoided to undertake stress (Stephen Pheasent, 1996).



## 5.3 Ergonomics Analysis

To achieve the results of ergonomics analysis, selection design has been analysed using Rapid Upper Limb Assessment (RULA). Three positions used for obtaining analysis data are body static position on a chair, hand position while using computer appliances and waist rotation angle position during the work process. RULA (Rapid Upper Limb Assessment) is a survey method for use in workplace ergonomics research where work-related upper limb disorders are reported. This tool does not require any special equipment

to provide a quick assessment of neck, trunk and upper limb postures along with muscle function and the body's external loads. **Table 5.1** below a coding system is used to generate a list of actions that indicates the level of action needed to reduce injury risks.

**Table 5.1**: Rapid Upper Limb Assessment (RULA) level and Indication

| Grand Score | Action Level Colour | Indications |
|---|---|---|
| 1 or 2 | Green | Posture is acceptable if not maintained |
| 3 or 4 | Yellow | Further investigation needed. May need changes. |
| 5 or 6 | Orange | Further investigation and changes needed soon |
| 7 or more | Red | Investigation and changes required immediately |

The method uses diagrams of body postures and three scoring tables to provide evaluation of exposure to risk factors. These include number of movements, static muscle work, force and work postures determined by equipment and furniture. Three types of body postures predetermined are static, intermittent and repeated. For design studio FKM workplace the posture used is static as it describes the human's situation. **Table 5.2** below shows the variable posture of RULA analysis.

**Table 5.2**: Variables Posture of RULA Analysis

| Posture Variables | |
|---|---|
| Trunk flexion and extension | Left forearm supination and pronation |
| Trunk lateral flexion | Right forearm supination and pronation |
| Trunk twisting | Left upper arm flexion and extension |
| Neck flexion and extension | Right upper arm flexion and extension |
| Neck Twisting | Left forearm supination and pronation |

### 5.3.1 Analysis on Static Posture

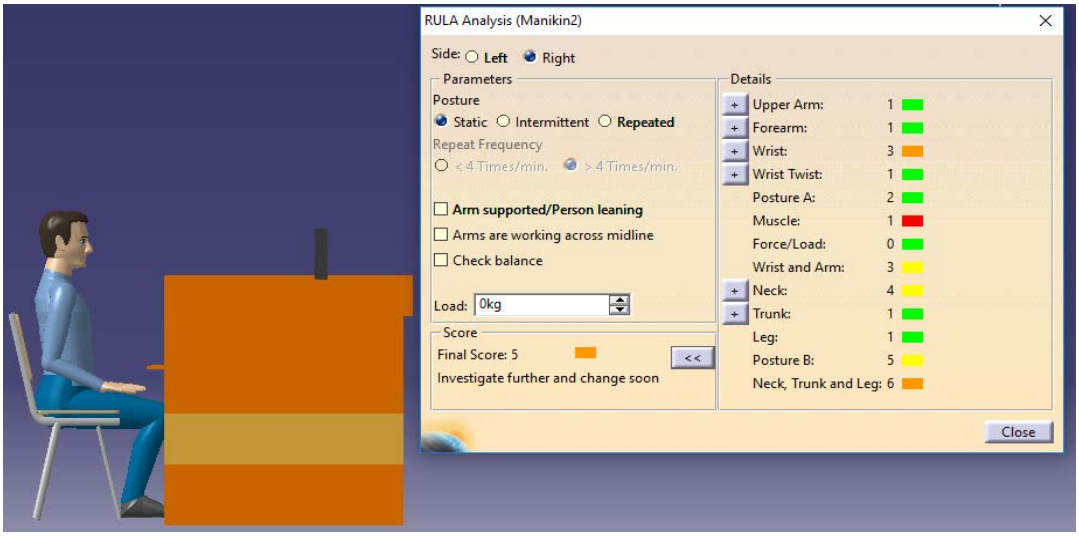



**Figure 5.1**: Analysis Static Posture of Existing Design

**Figure 5.1** illustrates the ergonomic result from the static position of a design. The final score is 5 for this analysis. This is because the body posture position, and the design of the chair does not support the entire backbone. In several ways this can cause injuries to people such as back, neck and shoulder ache. This shows that the neck is not supported by the chair and that results in 6. In this design, body postures such as wrist, neck and trunk affected in this analysis.

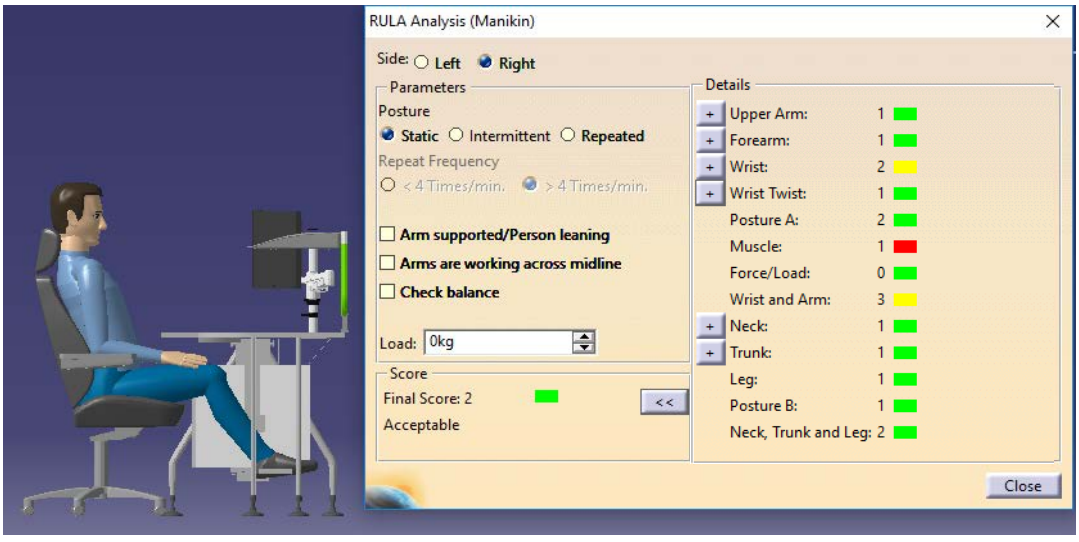



**Figure 5.2**: Analysis Static Posture of Concept Generation 1

**Figure 5.2** of the previous page shows the ergonomics outcome of the Rapid Upper Limb Assessment for the static position of Concept Generation 1. For this static posture analysis, the final score is 2. The result demonstrates good ergonomics when neck and trunk are well supported by the head rest. Ergonomic furniture design such as head rest is specifically designed to make the work environment more efficient and comfortable. A few changes can be made from the result to obtain the best result in ergonomics which is the value of 1. Good position can help with muscle weakness, pain and fatigue and also improve a student's productivity.

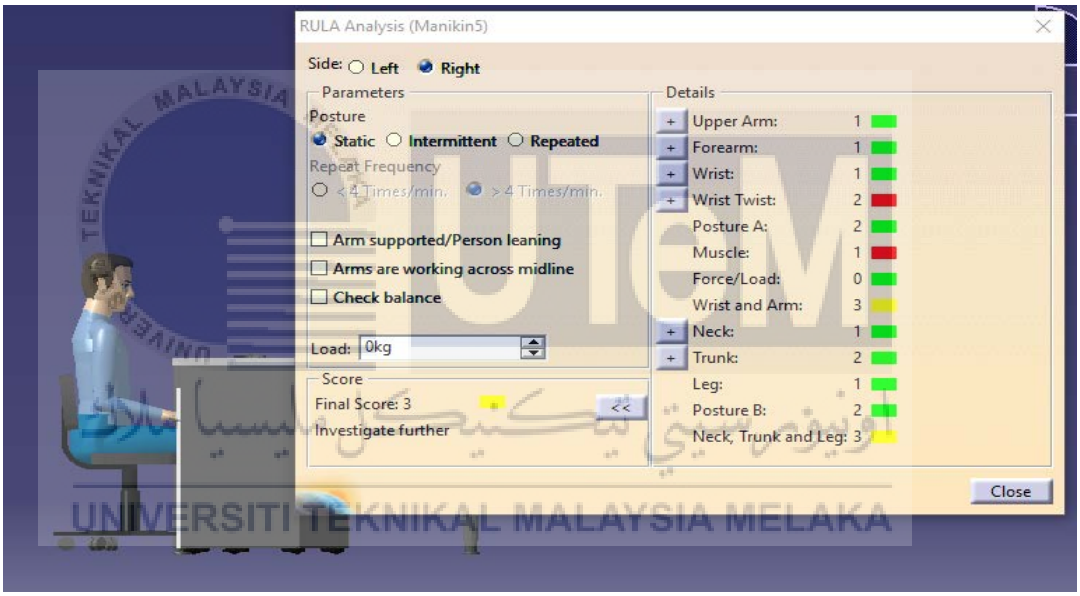



**Figure 5.3**: Analysis Static Posture of Concept Generation 3

The final analysis score for Concept Generation 3 static posture is explained in **Figure 5.3**. The end result is 3 and the ergonomics result can be improved by making a few changes. The result shows poor ergonomics, with high stress value especially on the student's arm and wrist. The result is mainly influenced by the student's arm, which is the forearm, wrist and wrist twist have the highest effect, which is 2 in red color. The arm rest chair effects the student's performance, where the student can put his hand on arm rest area as to reduce stress.

### 5.3.2 Analysis when using Computer Appliances

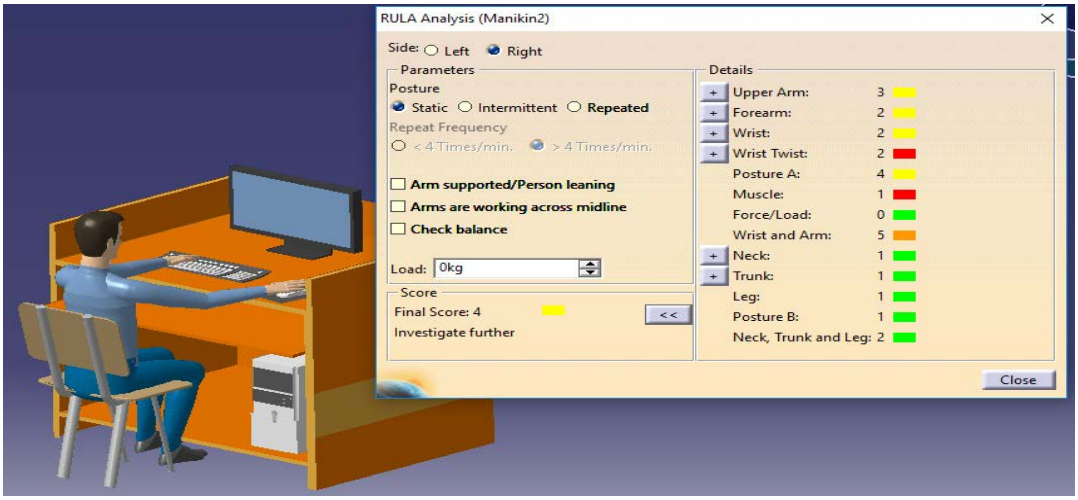



**Figure 5.4**: Analysis Manikin using Computer Appliances (Existing Design)

**Figure 5.4** shows the ergonomics result of student using computer appliances of an existing design. For this analysis the final score is 4. There may be several human body injuries such as backpain, neck and shoulder ache. In order to obtain the best ergonomic result, the human body position should be more investigated. It has poor ergonomic value, which mainly affects forearm and a wrist area. The human body posture that affect in this design are the wrist, neck and trunk.

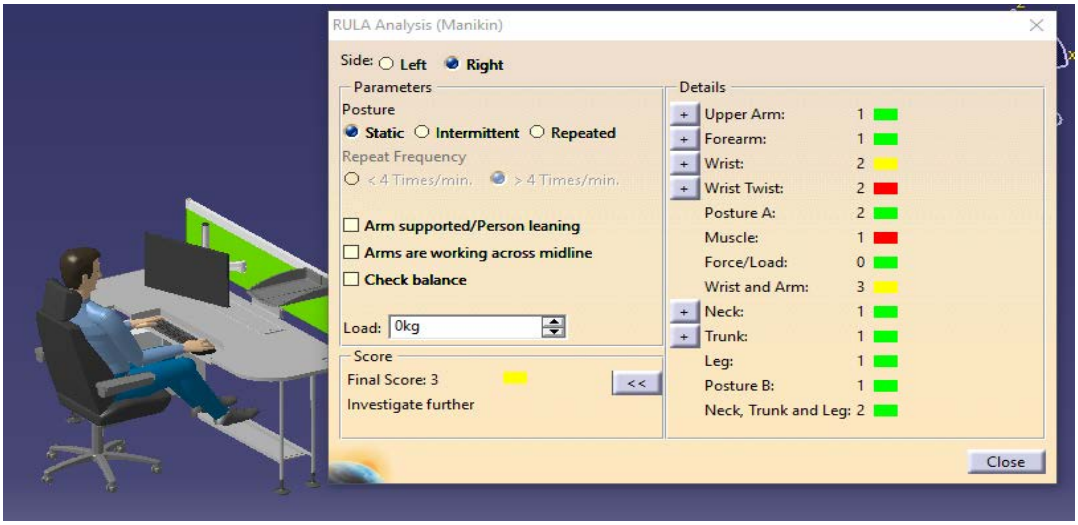



**Figure 5.5**: Analysis Manikin using Computer Appliances (Concept Generation 1)

The ergonomics result of the Concept Generation 1 Rapid Upper Limb Assessment analysis is shown from the previous page in **Figure 5.5**. The final score for this analysis of using computer aplliances is 3. The result shows a good result in ergonomics value . A few changes can be made from the result to obtain the best result in ergonomics which is the value of 1. In order to produce fatigue and prodcutive student, the S-shaped curvature of the spine, which is characteristic of good standing posture, should also be maintain.

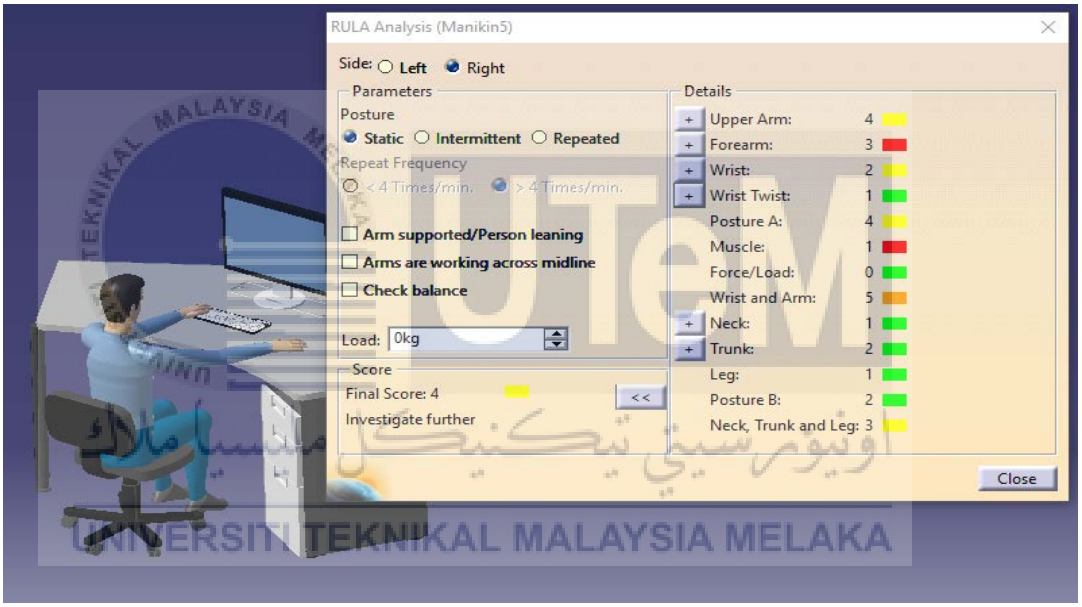



**Figure 5.6**: Analysis Manikin using Computer Appliances (Concept Generation 3)

**Figure 5.6** explains the final analysis score of student using computer appliances in Concept Generation 3. The final result is 4 and some modifications can be made to improve the result of ergonomics. The result shows poor ergonomics value in which the student's body was especially handled by high pressure and stress at the upper body area. This means more stress and strain occur on the human backbone, because the trunk of the body is not supported by the back of the chair and this prevents back pain.

### 5.3.3 Analysis on Rotation of Waist (60°)

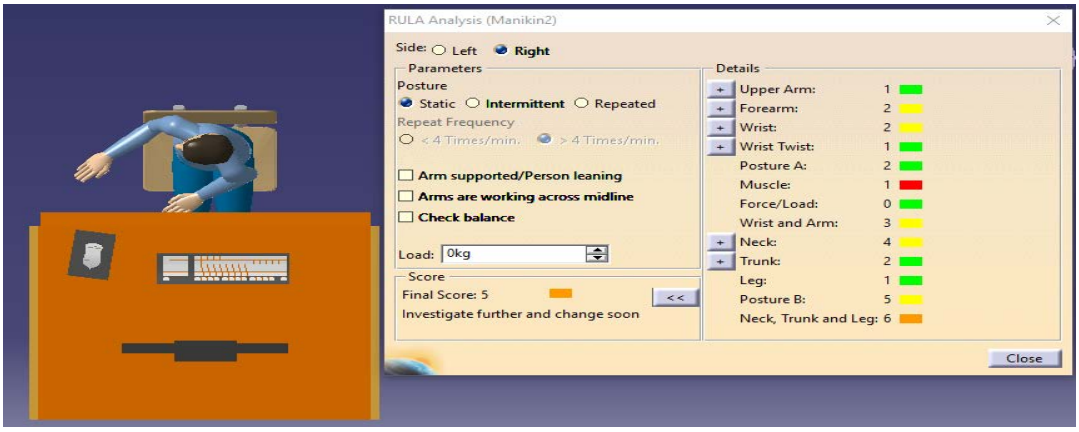



**Figure 5.7**: Analysis Waist Rotation on Existing Design

**Figure 5.7** illustrates the ergonomic result of a student waist rotation for certain angle. For this analysis, the final score is 5. It's because of the position of the body and the workspace layout. The risk of injury caused by an uncomfortable posture or the repeated nature of a work can discomfort students and cause stress related to the work. The result demonstrates a poor ergonomic value where student find it difficult to move around and rotate due to the lack of spaces at their workspace. The human body posture in this design are the waist, neck and trunk.

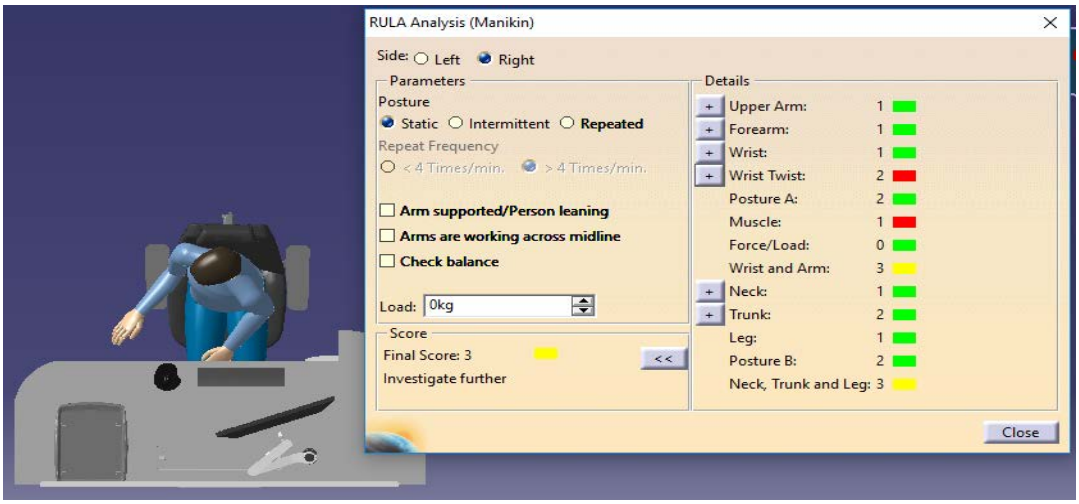



**Figure 5.8**: Analysis Waist Rotation on Concept Generation 1

In **Figure 5.8** from the previous page, the ergonomics from Rapid Upper Limb Assessment analysis are shown. For this waist rotation angle analysis, the final score is 3. The result shows that the neck and trunk are well supported by the head rest, reducing the stress level in that area. As a result, some changes can be made to achieve the best result of ergonomics which is the value of 1. Ergonomic chairs ensure a safe and steady position is maintained in the body of the user to reduce spine, neck and hip stress.


**Figure 5.9**: Analysis Waist Rotation on Concept Generation 3

The final analysis score on Concept Generation 3's of a student waist angle rotation and movement is explained in **figure 5.9**. The end result is 4 and the ergonomics result can be improved with a few changes to be made. The result shows poor ergonomics value, especially for the student's hand with high stress and pressure at the uppper body area. The arm rest chair affects the performance of a student who can put his or her hand on the armrest in order to reduce stress. In this design, body postures such as waist, forearm and neck affected in this analysis.

## 5.4 Comparison between Existing Design and Concept Generations

In order to identify differences in ergonomic value, analysis results between the current existing design and concepts selection are analyzed and compared. If the new design is less ergonomic than the existing ones, it is necessary to re-select the concept to achieve the best ergonomics value.

### 5.4.1 Comparison on Static Posture Analysis

**Table 5.3**: Static Posture Analysis Result

| **Existing Design** | | **Concept Generation 1** | | **Concept Generation 3** | |
|---|---|---|---|---|---|
| Body Part | Score | Body Part | Score | Body Part | Score |
| Upper arm | 1 | Upper arm | 1 | Upper arm | 1 |
| Forearm | 1 | Forearm | 1 | Forearm | 1 |
| Wrist | 3 | Wrist | 2 | Wrist | 1 |
| Wrist twist | 1 | Wrist twist | 1 | Wrist twist | 2 |
| Muscle | 1 | Muscle | 1 | Muscle | 1 |
| Wrist and arm | 3 | Wrist and arm | 3 | Wrist and arm | 3 |
| Neck | 4 | Neck | 1 | Neck | 1 |
| Trunk | 1 | Trunk | 1 | Trunk | 2 |
| Leg | 1 | Leg | 1 | Leg | 1 |
| Neck, Trunk, and Leg | 6 | Neck, Trunk, and Leg | 2 | Neck, Trunk, and Leg | 3 |
| **Final Score** | **5** | **Final Score** | **2** | **Final Score** | **3** |

The comparison between existing and concept designs in the student body's static posture is explained in **Table 5.3**. Compared to existing designs and Concept Generation 3, this shows a good and ergonomic result in Concept Generation 1. The final score for this static analysis is 2. The result shows good ergonomics value when

the head rest supports neck and trunk well. The existing design shows the final score of 5 and shows that the design needs to do more research in order to improve the value of ergonomics. With concept generation 1, less stress is shown and several injuries, such as back pain, neck and shoulder ache can be reduced.

### 5.4.2 Comparison Analysis when using Computer Appliances

**Table 5.4**: Using Computer Appliances Analysis Result

| **Existing Design** | | **Concept Generation 1** | | **Concept Generation 3** | |
|---|---|---|---|---|---|
| Body Part | Score | Body Part | Score | Body Part | Score |
| Upper arm | 3 | Upper arm | 1 | Upper arm | 4 |
| Forearm | 2 | Forearm | 1 | Forearm | 3 |
| Wrist | 2 | Wrist | 2 | Wrist | 2 |
| Wrist twist | 2 | Wrist twist | 2 | Wrist twist | 1 |
| Muscle | 1 | Muscle | 1 | Muscle | 1 |
| Wrist and arm | 5 | Wrist and arm | 3 | Wrist and arm | 5 |
| Neck | 1 | Neck | 1 | Neck | 1 |
| Trunk | 1 | Trunk | 2 | Trunk | 2 |
| Leg | 1 | Leg | 1 | Leg | 1 |
| Neck, Trunk, and Leg | 2 | Neck, Trunk, and Leg | 2 | Neck, Trunk, and Leg | 3 |
| **Final Score** | **4** | **Final Score** | **3** | **Final Score** | **4** |

**Table 5.4** shows the ergonomically comparable design for the analysis of the Rapid Upper Limb Assessment. Existing design and concept generation 3 shows the same final score that is 4 from the result. The result for both designs is a poor ergonomic value, mainly affecting the forearm and wrist areas. This shows the table's difference height playing a major role in creating body stress at the upper body section such as wrist, forearm, and arm. In the meantime, concept generation 1 shows

a significantly better final score of 3 than the other design. In the future, the outcome of the new design can be replaced with the green color action level (1-2) to achieve the best result in RULA scoring.

### 5.4.3 Comparison on Waist Rotation (60°)

**Table 5.5**: Waist Rotation Analysis Result

| **Existing Design** | | **Concept Generation 1** | | **Concept Generation 3** | |
|---|---|---|---|---|---|
| Body Part | Score | Body Part | Score | Body Part | Score |
| Upper arm | 1 | Upper arm | 1 | Upper arm | 1 |
| Forearm | 2 | Forearm | 1 | Forearm | 1 |
| Wrist | 2 | Wrist | 1 | Wrist | 3 |
| Wrist twist | 1 | Wrist twist | 2 | Wrist twist | 2 |
| Muscle | 1 | Muscle | 1 | Muscle | 1 |
| Wrist and arm | 3 | Wrist and arm | 3 | Wrist and arm | 4 |
| Neck | 4 | Neck | 1 | Neck | 1 |
| Trunk | 2 | Trunk | 2 | Trunk | 3 |
| Leg | 1 | Leg | 1 | Leg | 1 |
| Neck, Trunk, and Leg | 6 | Neck, Trunk, and Leg | 3 | Neck, Trunk, and Leg | 4 |
| **Final Score** | **5** | **Final Score** | **3** | **Final Score** | **4** |

There are differences in ergonomics resulting from the comparison made in **Table 5.5** between the designs. It shows a good ergonomics result compared to the other two designs with a value of 3 from the result of concept generation 1. The result is influenced by the chair type and arm rest. Because of the layout of the workspace, students are able to rotate around. Because of its physical characteristics, concept generation 1 basically supports the upper body area such as the upper arm, forearm,

wrist and neck. The arm rest chair has an impact on a student's performance that can put his or her hand on the armrest to reduce stress. Ergonomic chairs ensure that the user's body maintains a safe and stable position to reduce spine, neck and hip stress.

## 5.5 Choosing the Final Design

**Table 5.6**: Concept Generation 1 Final Score

| Body Position | Final Score |
|---|---|
| Static Posture | 2 |
| Using Computer Appliances | 3 |
| Waist Rotation 60° | 3 |

The Rapid Upper Limb Assessment (RULA) analysis shows that the final score value in these three positions which is the body's static position on a chair, the hand's position while using computer appliances, and the position of the waist rotation angle at the workplace. In these three conceptual designs, the concept generation 1 has the highest ergonomics score. The final score is 2 for the analysis of the static posture of concept generation 1 as shown on **Table 5.6** above. The result shows good value for ergonomics because the neck and trunk support the head rest well.

The final score for this analysis is 3 from the result of using concept generation 1 computer appliances. Compared to the other conceptual design, concept generation 1 has arm rest. The arm rest chair affects a student's performance that can put his or her hand on the armrest to lower stress level. The concept generation 1 shows the final value of 3 for the analysis of the waist rotation. The analysis shows that due to the physical characteristics of the chair and table, the wrist and forearm are well supported.

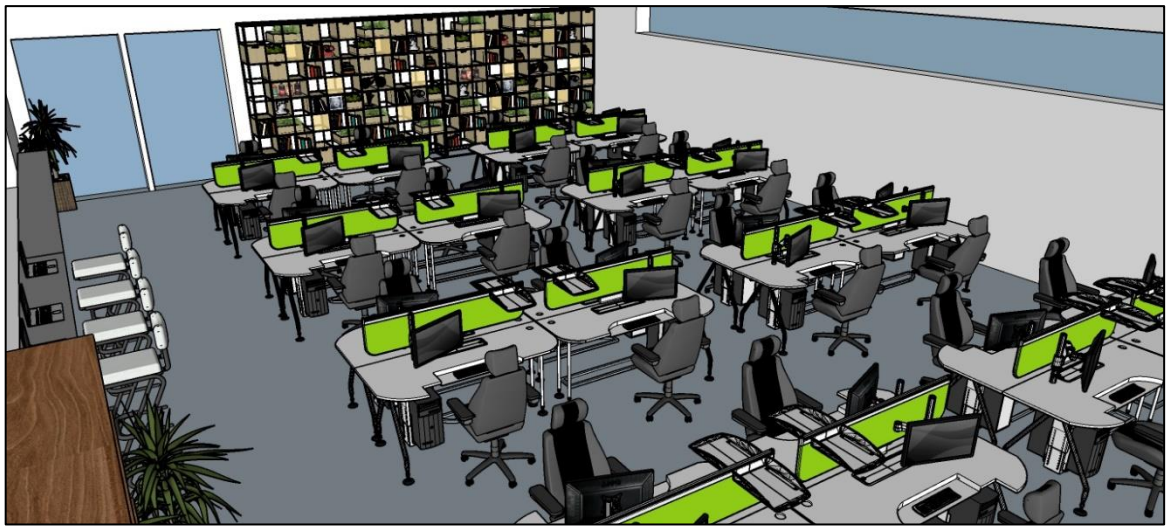


**Figure 5.10**: Concept Generation 1 Design Studio Layout

The design is suitable for students to develop new products and objects based on the concept generation 1 layout due to extended work benches, computer equipment and large boards and screen presentations. The layout of this studio design arrangement is organized systematically as shown on **Figure 5.10**. This makes it easier for students to move around and making it easier to control the class by creating an open and friendly classroom environment. The addition of ' relaxation area ' in a design studio, based on **Figure 5.11**, will have an impact on students by boosting their creativity and feeling more comfortable. Creative classroom can really transform the way students learn and apply it in their real life.

**Figure 5.11**: Extended Design Studio Spaces Concept Generation 1

## 5.6 Discussion

The purpose of this project study is to design and perform ergonomics analysis for the design studio (SRBK) of the Faculty of Mechanical Engineering. Design Studio FKM includes the posture of the human body during static movement during the workplace and the movement of the body angle. There is few position and movement of an individual body using Rapid Upper Limb Assessment (RULA) software to perform an ergonomic analysis. From the literature review and customer surveys, the information is collected by providing each customer with mail, e-mail, telephone or in-person links to this questionnaire and Studio Reka Bentuk (SRBK)'s existing design acts as a reference.

A few lists of customer requirements are listed from the data findings which are safety, comfort, cost, user-friendly and quality. The design process will be carried out using each identified specification to fulfill the desire of the customer. Four design concepts are generated to obtain the best new design concept. The Pugh Selection Method analysis and Weighted Decision Matrix were done to analyze the best concept design to be chosen in this project in order to select the best concept design. In comparison with the existing design, Concept Generation 1 and Concept Generation 3 were used. All three designs are analyzed using ergonomics analyzes to determine their final score.

Selection design was analyzed using Rapid Upper Limb Assessment (RULA) to achieve the results of ergonomics analysis. The result shows the individual work-value ergonomic posture. Good position can help with muscle weakness, pain and fatigue as well as enhance the productivity of a student. The result shows that Concept Generation 1 is more ergonomic than two other designs from the comparison. Concept Generation 1 can be used when using computer appliances to reduce student injury.

# CHAPTER 6

# CONCLUSION AND RECOMMENDATION

## 6.1 Conclusion

Based on the analysis done, it can be concluded that every part of the human body needs to be focused on ergonomics to avoid any unnecessary and harmful accidents. Starting with the literature review to ensure the project's understanding and subject until the conceptual design comes out and going into more detail until the ergonomic analysis is completed. In designing the design studio workplace, many other things need to be reconsidered, such as static body posture and the design studio layout. Also, the design selection method is a part of achieving the project goal.



The design task was carried out and the best conceptual design is chosen which is the generation of the concept 1. The analysis of the Pugh Selection Method and the Weighted Decision Matrix was conducted to analyze the best concept design to be selected in this project to select the best concept design. Compared to the existing design with the value of 2 in RULA scoring, the result of the concept generation 1 is much better from the analysis. The new selection design ensures that the body of the user is in a safe and stable position to reduce the stress of the spine, neck and hip. Potential accidents like backpain, neck pain, shoulder aches, headaches and pain in the upper body can be reduced from the ergonomics study. Hopefully, concept generation 1 can be used as a reference in the design studio's future development.

## 6.2 Recommendation for Future Works

There are several recommendations to develop a design studio FKM which can be optimized to ensure that the student is less likely to get injuries and that the choice of design can be redesigned in order to better result in the Rapid Upper Limb Assessment analysis. Furthermore, due to the result obtained, the design studio FKM layout can be a mock-up or model as a reference and guidance from the analysis of this project. Student posture analysis can be varied by carrying out the analysis on the future stress vibration analysis.

This final selection concept should always be reconsidered to achieve the best value for the principle of ergonomics. This is because new invention on the support of the structural human body is generated as the technology increases. However, only minor changes need to be made based on observations from the previous design. To achieve the best result at RULA rating, the results of the new design can in future be replaced until it achieves green color action level (1-2) RULA scoring.

## REFERENCES


Amick III, B.C., Robertson, M.M., DeRango, K., Bazzani, L., Moore, A., Rooney, T. and Harrist, R., 2003. *Effect of office ergonomics intervention on reducing musculoskeletal* symptoms. *Spine*, *28*(24), pp.2706-2711.

Candotti, C. T., Detogni Schmit, E. F., Pivotto, L. R., Raupp, E. G., Noll, M., Vieira, A., & Loss, J. F. (2018). *Back Pain and Body Posture Evaluation Instrument for Adults: Expansion and Reproducibility. Pain Management Nursing*, 19(4), 415–423.

Dockrell, S., O'Grady, E., Bennett, K., Mullarkey, C., Mc Connell, R., Ruddy, R., Twomey, S. and Flannery, C., 2012. *An investigation of the reliability of Rapid Upper Limb Assessment (RULA) as a method of assessment of children's computing posture. Applied ergonomics*, *43*(3), pp.632-636.

Dragomir, M., Banyai, D., Dragomir, D., Popescu, F., & Criste, A. (2016). *Efficiency and Resilience in Product Design by Using Morphological Charts. Energy Procedia, 85, 206–210.*

*Ergonomics,* School of Mechanical, Materials, Manufacturing Engineering and Management, University of Nottingham, pp 557-567.

Fernandes, G., Gonçalves, D. A. G., & Conti, P. (2018). *Musculoskeletal Disorders. Dental Clinics of North America.*

Gurr, K., Straker, L., & Moore, P. (1998). *Cultural hazards in the transfer of ergonomics technology. International Journal of Industrial Ergonomics, 22(4-5), 397–404.*

George E. Dieter & Linda C. Schmidt (2006) *Engineering Design, 4th Edition*, Mc Graw Hill Publishing.

Harisinghani, M.G., Blake, M.A., Saksena, M., Hahn, P.F., Gervais, D., Zalis, M., da Silva Dias Fernandes, L. and Mueller, P.R., 2004. *Importance and effects of altered workplace ergonomics in modern radiology suites*. *Radiographics*, *24*(2), pp.615-627.

John R. Wilson (2000) *Fundamentals of ergonomics in theory and practice, Applied*

Kim, I., Lindeman, K., & Masear, C. (2018). *New onset acute pulmonary edema after methylergonovine given during cesarean delivery of a patient with undiagnosed Raynaud's disease. International Journal of Obstetric Anesthesia.*



Kroemer Elbert, K. E., Kroemer, H. B., & Kroemer Hoffman, A. D. (2018). *Why and How to Do Ergonomics. Ergonomics, 647–657.*

Lynn McAtammey and E. Nigel Corlett (1993) RULA: *a survey method for the investigation of world-related upper limb disorders, Applied Ergonomics*, pp 91-99

Luo, C., Yu, L., Yang, E., Zhou, H., & Ren, P. (2019). *A Benchmark Image Dataset for Industrial Tools. Pattern Recognition Letters.*

Markku Matilla (1996*) Computer aided ergonomics and safety – A challenge for integrated ergonomics, International Journal of Industrial Ergonomics*, pp 309-314.

Martin Helander (2006) *A Guide to Human Factors and Ergonomics*, *2th Edition*, Taylor & Francis group, pp 3-6.

Mao, Q., Li, N., & Peña–Mora, F. (2019). *Quality Function Deployment-Based Framework for Improving the Resilience of Critical Infrastructure Systems. International Journal of Critical Infrastructure Protection*, 100304.

Nico J. Delleman, C.M. Haslegrave and Don B. Chiffin (2004) *Working Postures and Movement: Tools for Evaluation and Engineering,* United States of America, CRC press publishing.

Ramírez, Y., Cisternas, L. A., & Kraslawski, A. (2017). *Application of House of Quality in assessment of seawater pretreatment technologies. Journal of Cleaner Production, 148, 223–232.*

Salvendy, G. ed., 2012. *Handbook of human factors and ergonomics*. John Wiley & Sons.

Wojtowicz, J., 1995. *Virtual design studio* (Vol. 1). Hong Kong University Press.

**APPENDIX A**

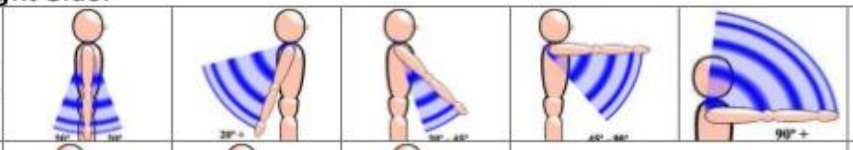
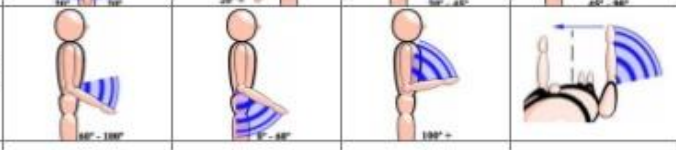
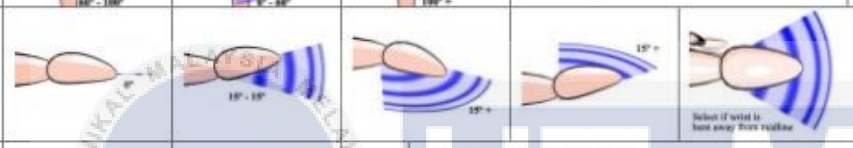
**(Existing Design-Studio Reka Bentuk)**

## APPENDIX B

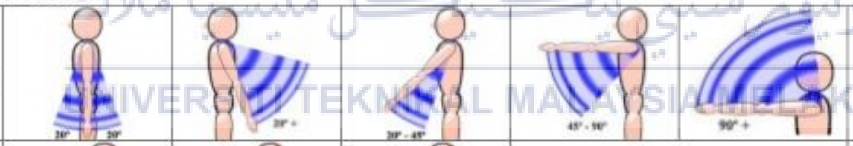
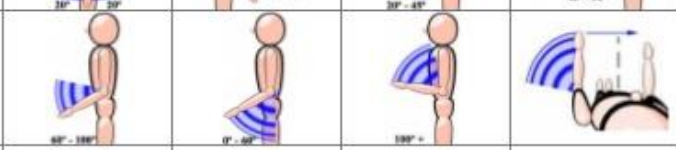
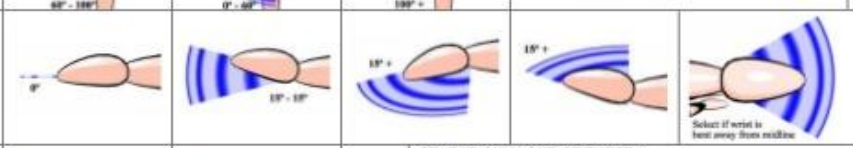
## (Rapid Upper Limb Assessment)

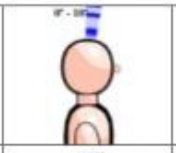
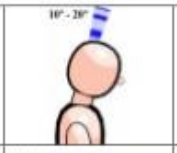
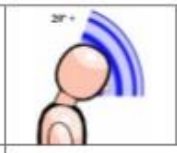
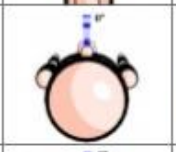
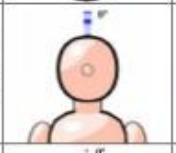
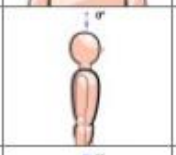
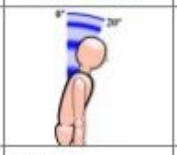
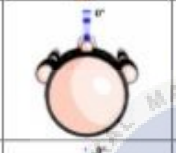
| RAPID UPPER LIMB ASSESSMENT | | |
|---|---|---|
| Client: | Date/time: | Assessor: |

**Right Side:**

| | | |
|---|---|---|
| Right Upper Arm |  | ❑ Shoulder is raised<br>❑ Upper arm is abducted<br>❑ Leaning or supporting the weight of the arm |
| Right Lower Arm |  | ❑ Working across the midline of the body or out to the side |
| Right Wrist |  | ❑ Wrist is bent away from midline |
| Right Wrist Twist |  Force & Load for the Right hand side | SELECT ONLY ONE OF THESE:<br>❑ No resistance ❑ less than 2kg intermittent load or force<br>❑ 2–10kg intermittent load or force<br>❑ 2–10kg static load ❑ 2-10kg repeated loads or forces ❑ 10kg or more intermittent load or force<br>❑ 10kg static load ❑ 10kg repeated loads or forces ❑ Shock or forces with rapid build-up |
| Muscle Use | ❑ Posture is mainly static, e.g. held for longer than 1 minute or repeated more than 4 times per minute | |

**Left Side:**

| | | |
|---|---|---|
| Left Upper Arm |  | ❑ Shoulder is raised<br>❑ Upper arm is abducted<br>❑ Leaning or supporting the weight of the arm |
| Left Lower Arm |  | ❑ Working across the midline of the body or out to the side |
| Left Wrist |  | ❑ Wrist is bent away from midline |
| Left Wrist Twist |  Force & Load for the Right hand side | SELECT ONLY ONE OF THESE:<br>❑ No resistance ❑ less than 2kg intermittent load or force<br>❑ 2–10kg intermittent load or force<br>❑ 2–10kg static load ❑ 2-10kg repeated loads or forces ❑ 10kg or more intermittent load or force<br>❑ 10kg static load ❑ 10kg repeated loads or forces ❑ Shock or forces with rapid build-up |
| Muscle Use | ❑ Posture is mainly static, e.g. held for longer than 1 minute or repeated more than 4 times per minute | |

| | | | | | |
|---|---|---|---|---|---|
| Neck |  |  |  |  | |
| Neck Twist |  |  | | | |
| Neck Side-bend |  |  | | | |
| Trunk |  |  |  |  | |
| Trunk Twist |  |  | | | |
| Trunk Side-bend |  |  | | | |
| Legs |  | Legs and feet are well supported and in an evenly balanced posture. |  | Legs and feet are NOT evenly balanced and supported. | |
| Force & Load for the neck, trunk and legs | SELECT ONLY ONE OF THESE:<br>❑ No resistance ❑ less than 2kg intermittent load or force<br>❑ 2–10kg intermittent load or force<br>❑ 2–10kg static load ❑ 2-10kg repeated loads or forces ❑ 10kg or more intermittent load or force<br>❑ 10kg static load ❑ 10kg repeated loads or forces ❑ Shock or forces with rapid build-up | | | | |
| Muscle Use | ❑ Posture is mainly static, e.g. held for longer than 1 minute or repeated more than 4 times per minute | | | | |

Whilst COPE Occupational Health and Ergonomic Services Ltd (COPE) and Osmond Group Limited (Osmond) have taken every care in preparing this resource, it must be used according to the guidelines based on the original article* by Prof E.N. Corlett and Dr L. McAtamney.

No responsibility will be taken by COPE or Osmond in the use of this resource.

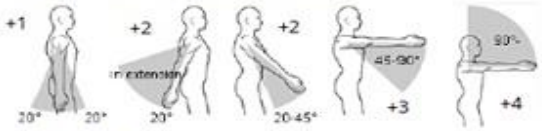
RULA provides a score of a snapshot of the activity as part of a rapid screening tool. The user should refer to the original article* to check the detail of the scoring and correct use of RULA scores. Further investigation and actions may be required.

For further information on methodology, please refer to our on-line guidance at **www.rula.co.uk** or refer to:
McAtamney, L and Corlett, E.N. Reducing the risks of work related upper limb disorders - A guide and methods. Published by: Institute for Occupational Ergonomics, University of Nottingham, Nottingham NG7 2RD, UK. (1992). Tel: +44 (0)115 9514005 for details.

*McAtamney, L. and Corlett, E.N. "RULA -: A survey method for investigation of work-related upper limb disorders. Applied Ergonomics 1993, 24(2), 91-99

## A. Arm and Wrist Analysis

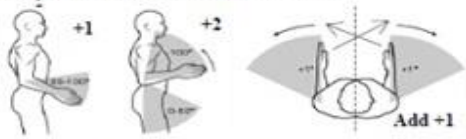
**Step 1: Locate Upper Arm Position:**




Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

**3** Upper Arm Score

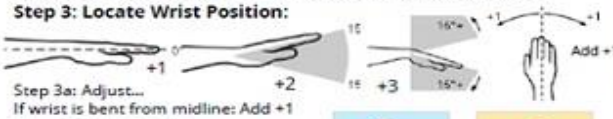
**Step 2: Locate Lower Arm Position:**




**2** Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

**Step 3: Locate Wrist Position:**




Step 3a: Adjust...
If wrist is bent from midline: Add +1

**Step 4: Wrist Twist:**
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

**2** Wrist Twist Score

**4** Wrist Score

**Step 5: Look-up Posture Score in Table A:**
Using values from steps 1-4 above, locate score in Table A

**5** Posture Score A

**Step 6: Add Muscle Use Score**
If posture mainly static (i.e. held>10 minutes).
Or if action repeated occurs 4X per minute: +1

**0** Muscle Use Score

**Step 7: Add Force/Load Score**
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

**2** Force / Load Score

**Step 8: Find Row in Table C**
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

**7** Wrist & Arm Score

### Scores

Table A

| Upper Arm | Lower Arm | Wrist Score 1 Wrist Twist 1 | 1 2 | Wrist Score 2 Wrist Twist 1 | 2 2 | Wrist Score 3 Wrist Twist 1 | 2 2 | Wrist Score 4 Wrist Twist 1 | 2 2 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
| | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 |
| 2 | 1 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
| 3 | 1 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 |
| | 2 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
| | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| 4 | 1 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| | 2 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 |
| 5 | 1 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 7 |
| | 2 | 5 | 6 | 6 | 6 | 6 | 7 | 7 | 7 |
| | 3 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 8 |
| 6 | 1 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 9 |
| | 2 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 |
| | 3 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

Table C

| Wrist / Arm Score | Neck, Trunk, Leg Score 1 | 2 | 3 | 4 | 5 | 6 | 7+ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 |
| 2 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 3 | 3 | 3 | 3 | 4 | 4 | 5 | 6 |
| 4 | 3 | 3 | 3 | 4 | 5 | 6 | 6 |
| 5 | 4 | 4 | 4 | 5 | 6 | 7 | 7 |
| 6 | 4 | 4 | 5 | 6 | 6 | 7 | 7 |
| 7 | 5 | 5 | 6 | 6 | 7 | 7 | 7 |
| 8+ | 5 | 5 | 6 | 7 | 7 | 7 | 7 |

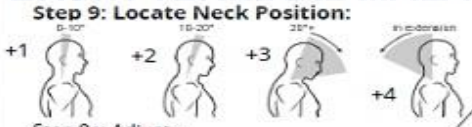
**Scoring:** (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score



## B. Neck, Trunk and Leg Analysis

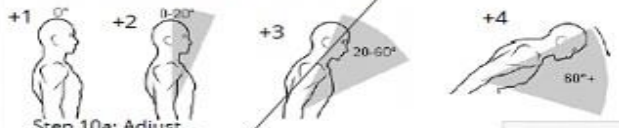
**Step 9: Locate Neck Position:**




**3** Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

**Step 10: Locate Trunk Position:**




Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

**2** Trunk Score

**Step 11: Legs:**
If legs and feet are supported: +1
If not: +2

**1** Leg Score

Table B: Trunk Posture Score

| Neck Posture Score | 1 Legs 1 | 1 2 | 2 Legs 1 | 2 2 | 3 Legs 1 | 3 2 | 4 Legs 1 | 4 2 | 5 Legs 1 | 5 2 | 6 Legs 1 | 6 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
| 2 | 2 | 3 | 2 | 3 | 4 | 5 | 5 | 5 | 6 | 7 | 7 | 7 |
| 3 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 | 7 |
| 4 | 5 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 8 | 8 |
| 5 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| 6 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 |

**FIGURE 1:** Postures adopted during working.

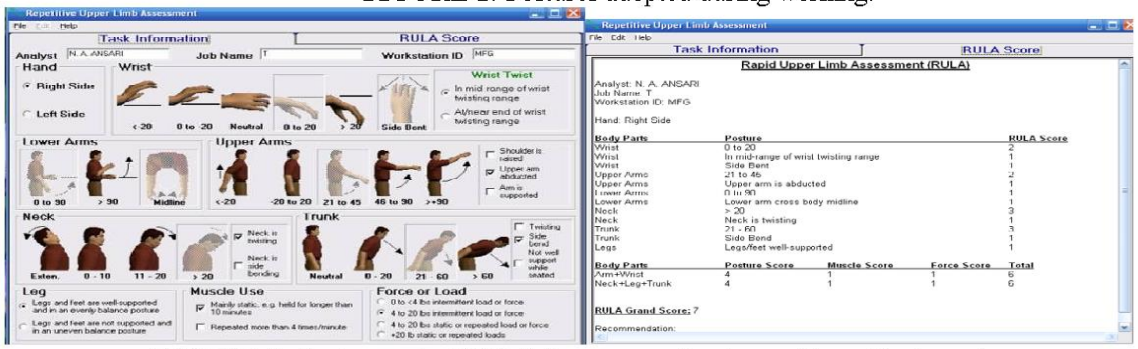
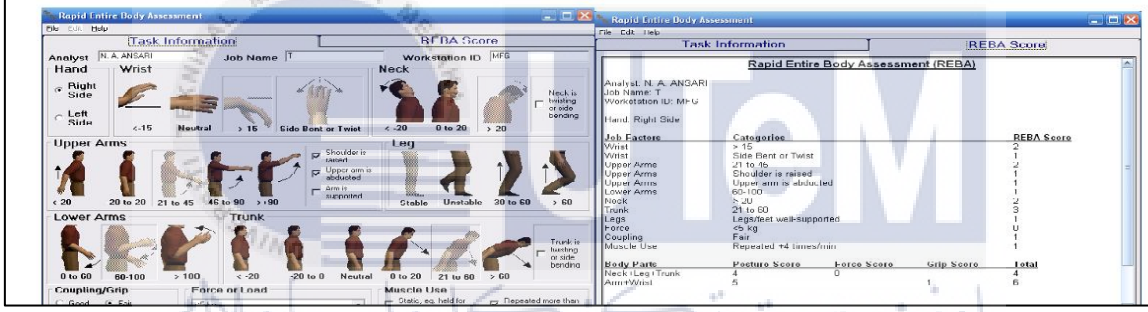
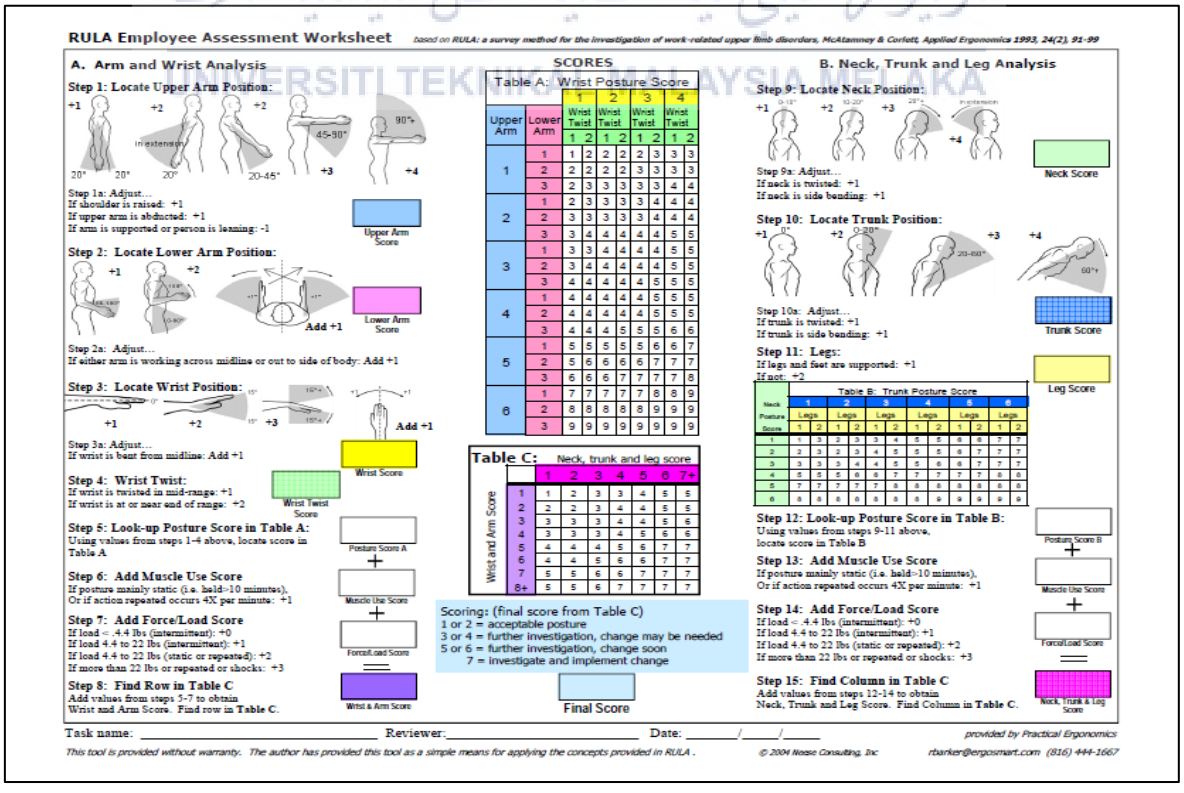


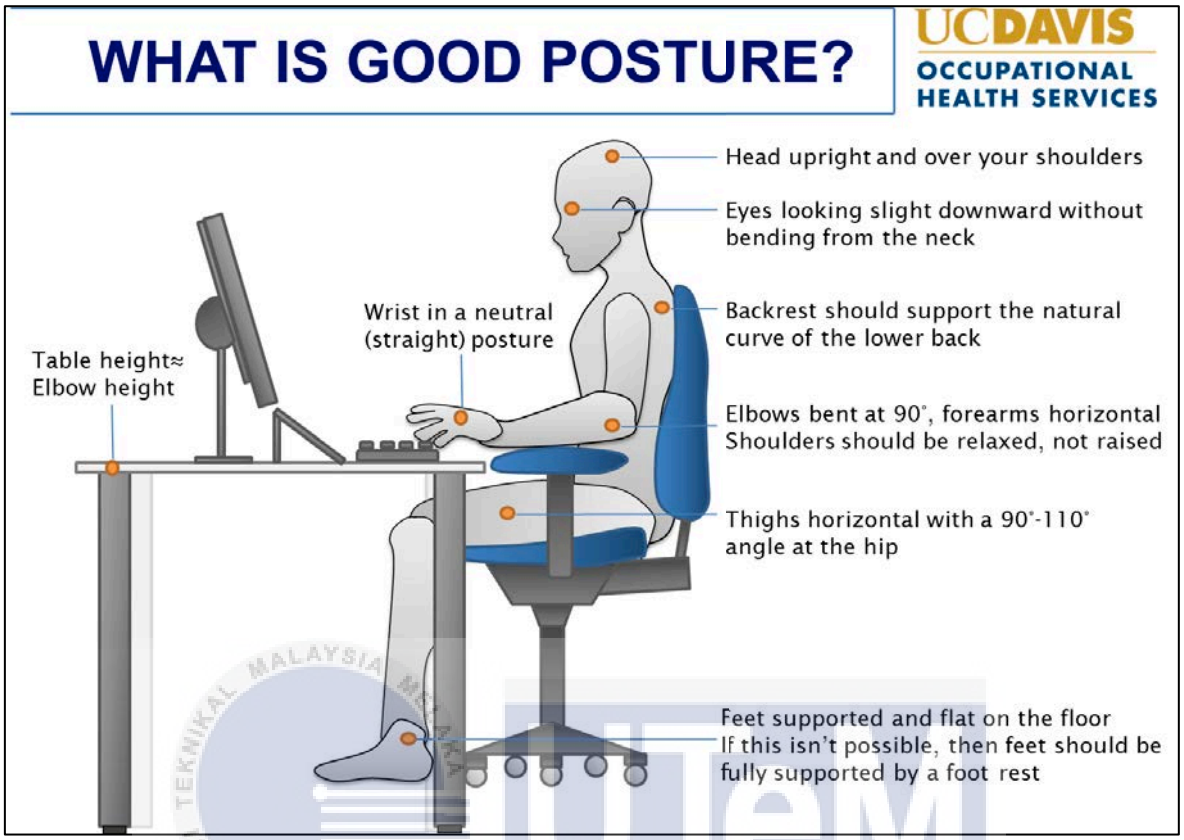
**FIGURE 2:** Assignment of RULA Score according to position of body part (Source: Ergointelligence™ Software.)

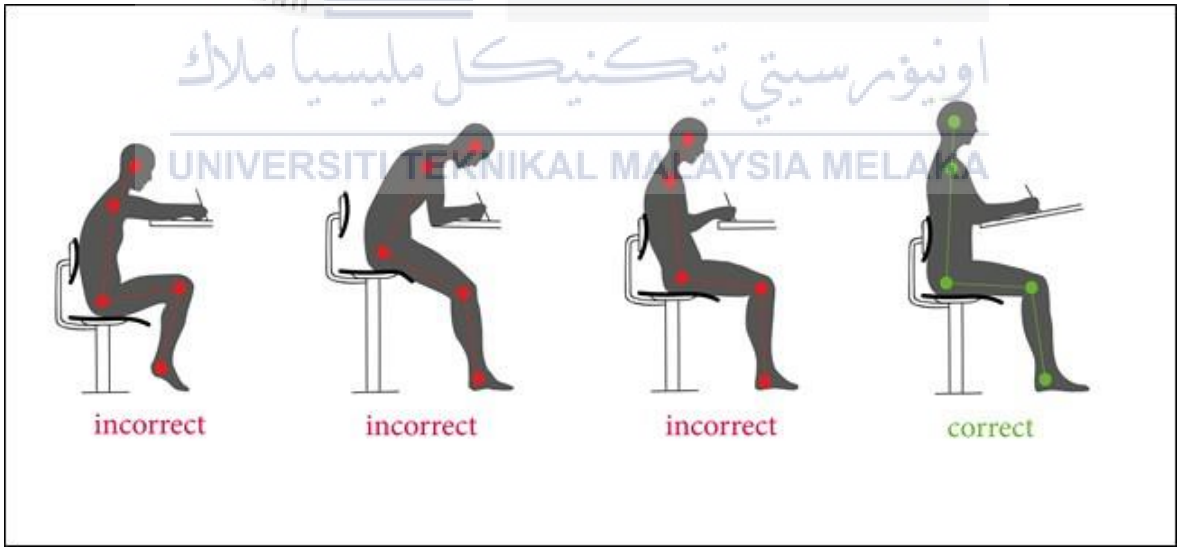




**APPENDIX C**

**(Ergonomics Body Posture)**



# Office ergonomics start with A.R.M.S.

## A is for adjustment and alignment

A simple chair adjustment makes a huge difference, says Karen Bitzer, occupational therapist and rehab manager at University Hospitals Case Medical Center.

Adjust the height of your chair, back rest and armrests, so that your elbows, hips and knees are bent at a 90 degree angle, and your forearms and thighs are parallel to the ground.

Ensure that your feet are parallel to the floor and your wrists are level with your desk.

If you work in front of a computer, adjust your monitor to about eye-level, so that you're glancing slightly down.

## R is for relaxation

Taking a break is beneficial to both your mind and body, Bitzer says. When your muscles are constantly contracting, toxins begin to build up. Relaxing improves circulation, removing those toxins and providing oxygen to your tissues

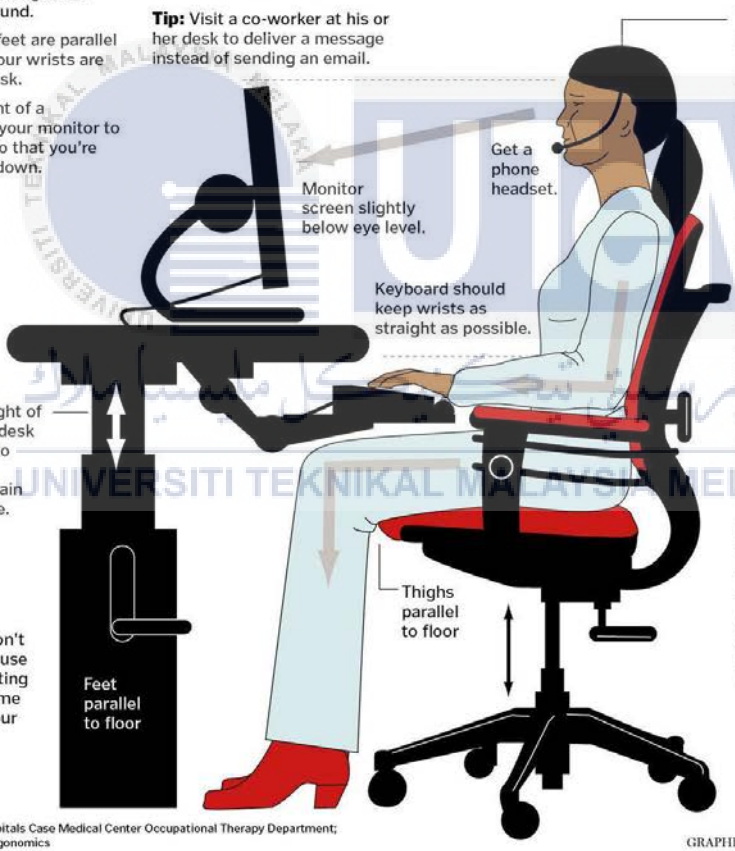
**Tip:** Visit a co-worker at his or her desk to deliver a message instead of sending an email.

## M is for motion

"The next posture is the best posture," says Gary Allread, program director for the Ohio State Institute for Ergonomics. "There's no one bad posture as long as you don't use that posture all day long." So mix up the muscles you're using throughout the day.

## S is for standing and safety

Stand at every opportunity, suggests Tom Adams, an ergonomist at the Cleveland Clinic. Stand up during meetings, or while you're talking on the phone.




**Tip:** If you spend more than 30 percent of your day on the phone, use a headset to avoid straining your neck. Position the phone on your non-dominant side so that you can easily jot down notes as you talk.

**Tip:** Every half hour, take a micro-break for a minute or two, Bitzer suggests.

1. Let your arms hang down to your sides and shake out your hands and wriggle your fingers.
2. Shrug your shoulders, then move them in a circular motion first back then forward. Finally, pull your shoulder blades together and release them.
3. Pump your ankles and point and flex your feet.
4. Straighten and bend your legs at the knee.
5. Cover your eyes for a few seconds and then focus them on something on the distance to prevent eye strain.

**Tip:** If your feet don't touch the ground, use a footrest. Supporting your feet takes some of the strain off your back.

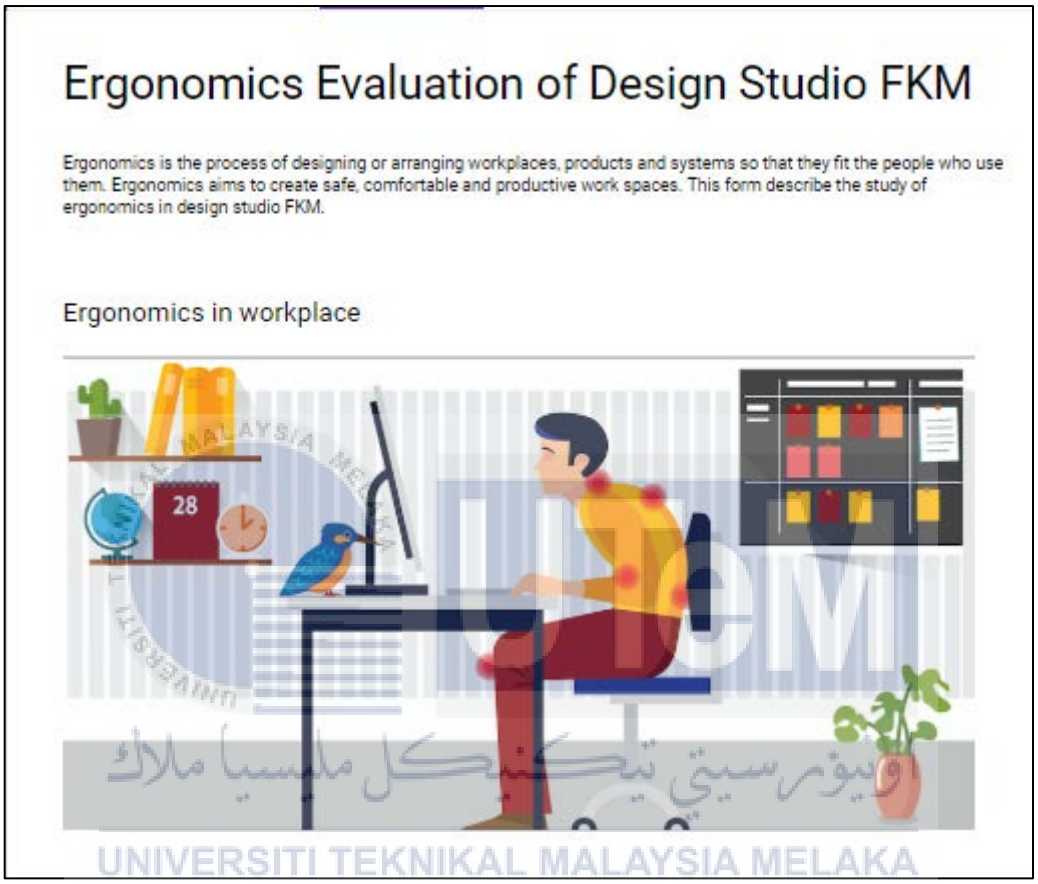
— *Natalie Villacorta, The Plain Dealer*

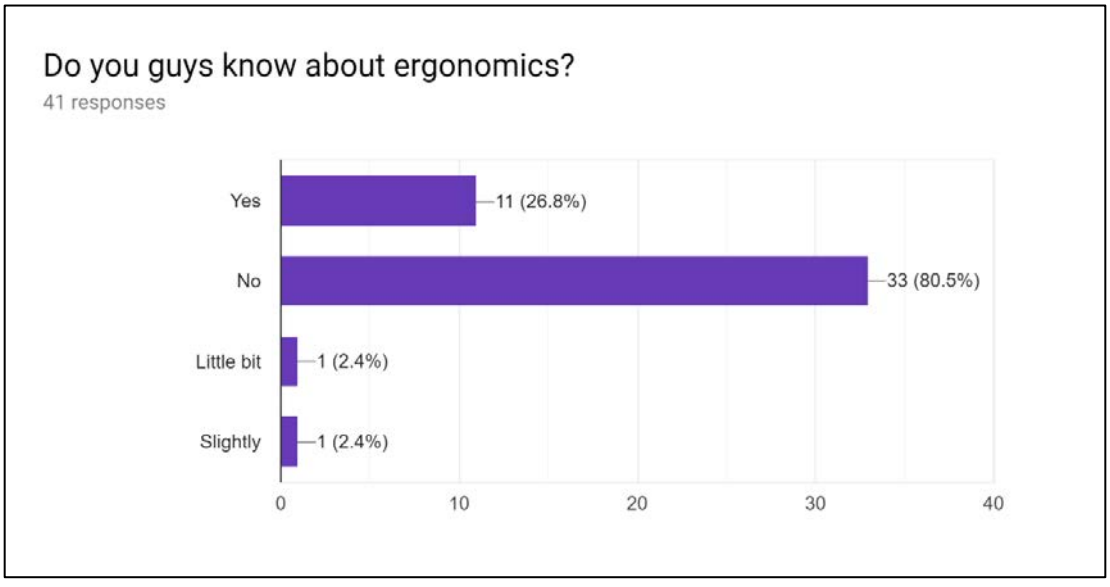
SOURCES: University Hospitals Case Medical Center Occupational Therapy Department; Ohio State Institute for Ergonomics

GRAPHIC BY KEN MARSHALL | THE PLAIN DEALER

**APPENDIX D**

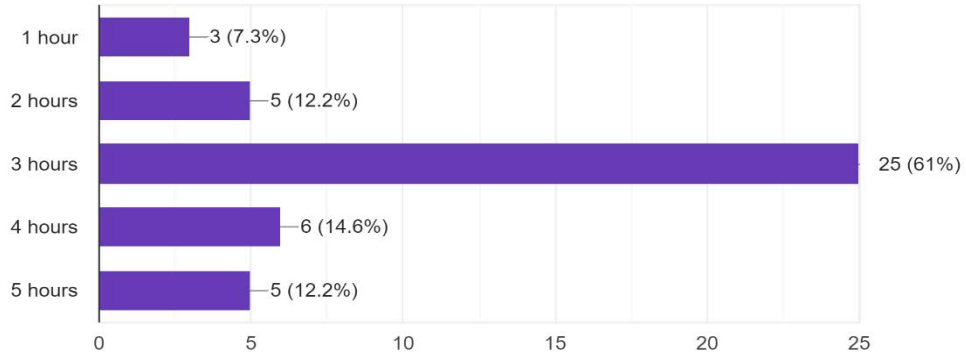
**(Sample Questionnaire)**



How many hours did you spent in your design studio?

41 responses



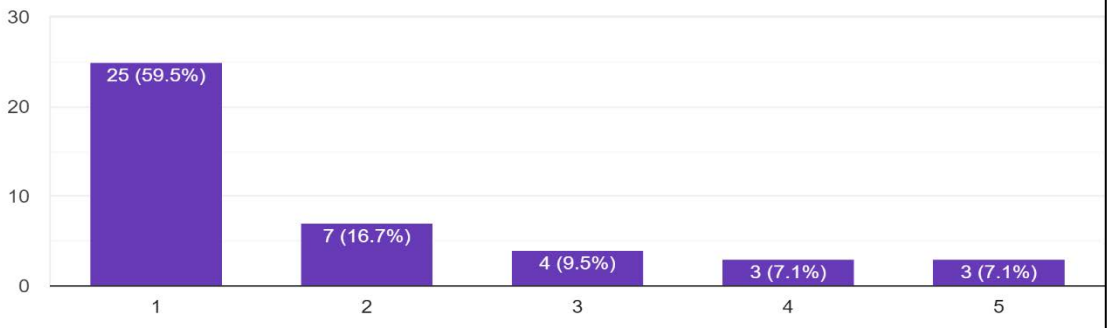

Does your chair support your backbone?

42 responses



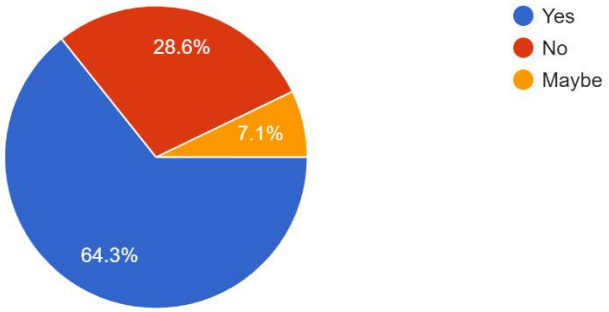

From a scale of 1 until 5 how comfortable is your workstation in design studio ?

42 responses



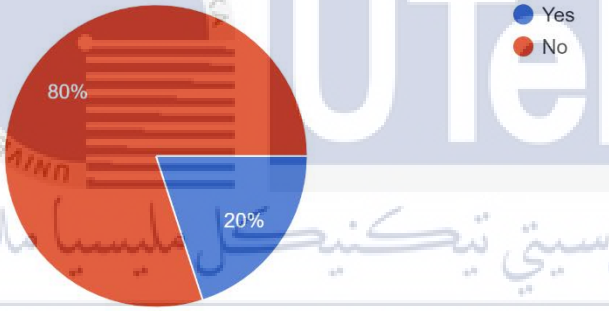
Do you ever experienced several pains (neck, backbone, shoulder) while doing your work at your workstation?

42 responses




Are your eyes gazing down at your normal cursor position?

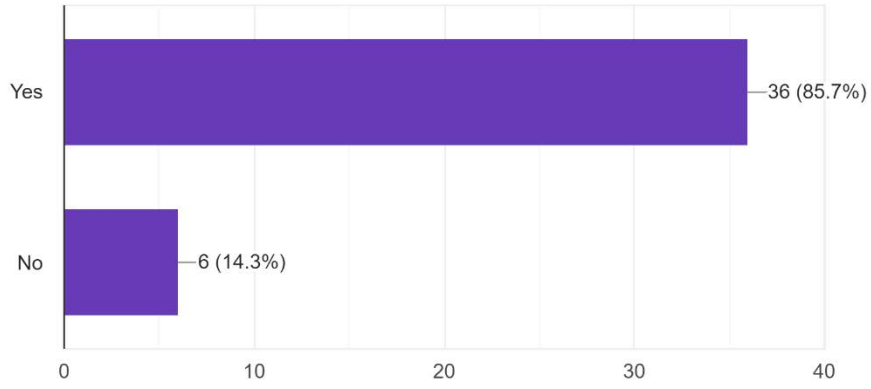
40 responses





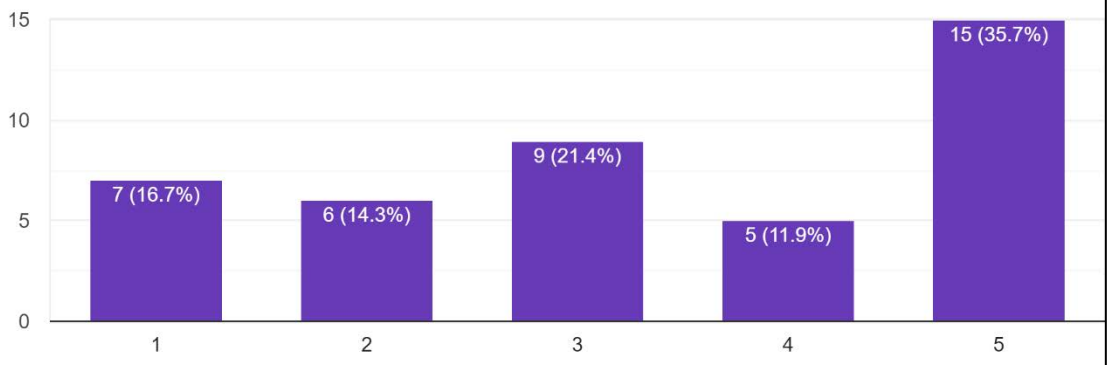

Is there anything below your desk affecting where you put your feet?

42 responses



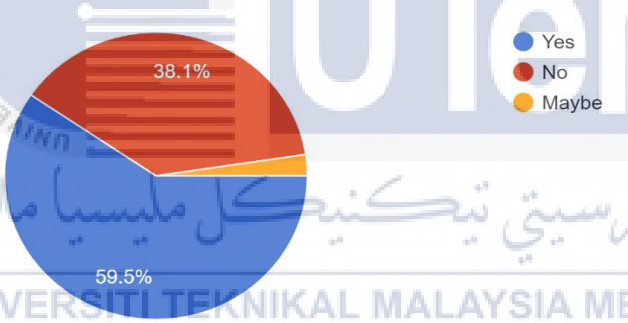
Are you interrupted form the same side you sit regularly as example a colleague next to you are too near?

42 responses




Is the lighting above your desk is suitable? too light or too dark?

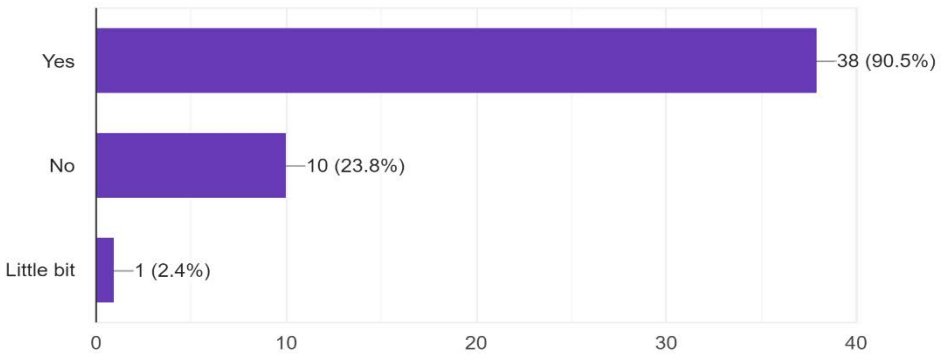
42 responses





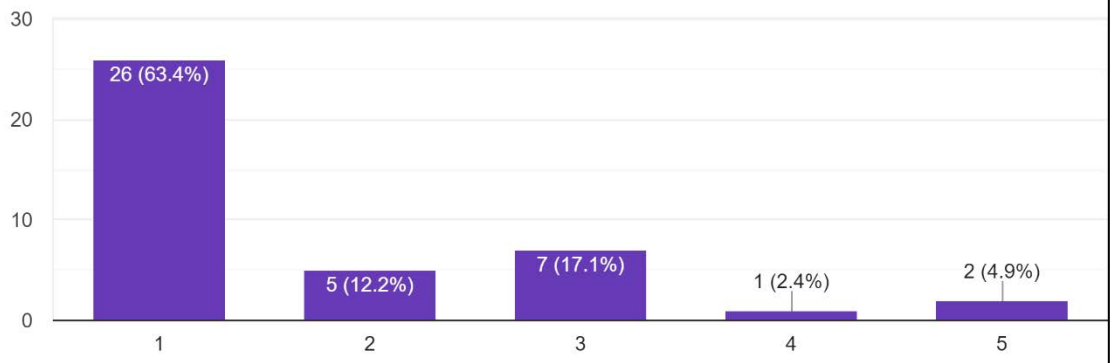

Do you feel you are tensing your neck or shoulders to keep your hands in position over keyboard?

42 responses



Does class layout play a major part in your productivity?

41 responses




Does your workplace affect your productivity and performance?

42 responses