Design and Fabrication of a Work Desk with Integrated Charging Ports, Desk Lamp and Storage Capability

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Abstract. This paper presents the design, development, and fabrication of a new work desk with integrated charging ports, desk lamp and storage capability for students’ use at the Outdoor Discovery Centre (ODC) hub at Jerudong International School (JIS), Brunei Darussalam. It contains a solar-powered lamp to provide light for students while conducting projects in the hub and storage compartments for students to place their belongings. It can organize and store wires, solar charge controllers, and switch box of a solar power system. Removable fans can be connected to the desk for students’ comfort. Charging ports are provided in the desk to charge electronic devices. The dimensions of the desk are based on anthropometric data of students of ages 14 - 18 years old. Feasible concepts of the product are generated and the final concept is selected based on product specifications such as aesthetics, cost, function, size, materials, environment-friendliness, and safety. The product is termed a better solution for use in ODC hub by its in-charge, Miss Follows Smith and the in-charge of renewable energy project at JIS, Dr. Lloyd.

1. Introduction
In today’s technological era, majority of work desks used in schools, offices, and homes have some sort of electronic device operated on the desk. This device may either be a computer, laptop, smartphone or a tablet all of which need electrical power to be charged and operated. Additionally, in order to create a wireless future, the innovation in electronic products that previously did not need charging, such as earphones and headphones, now need to be repeatedly charged after these products were made wireless. Innovation in modern technology has also given rise to the production of ‘smart’ electronic devices, such as smart speakers and smartwatches. These ‘smart’ devices have become very popular amongst the average consumers, resulting in an increased need for individuals to charge more devices.

Extension cables are normally used to charge these electronic devices. However, if every work desk needs at least one extension cable, there is a need for desks with integrated sockets and Universal Serial Bus (USB) ports, preferably, on top of the desk surface. This allows the user to directly plug in any device into available power sockets without the need to get up from their chair. To add to this, extension cables usually lie on the floor, making them unattractive and a serious tripping hazards, which could be harmful to people and the electronic equipment.

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Furthermore, study lamps are usually used with work desks as a means of providing light when studying. Study lamps also need to be connected to a power source and therefore, connected to an extension cable. A problem with desk lamps in the current market is that they need a large base to prevent the risk of toppling over. This adds on to the overall cost of the product making desk lamps expensive. A large base also takes up a lot of space on a desk surface, leaving less space for the user to place his / her items. Therefore, there is a need for lamps with a smaller base size without sacrificing the intensity of light produced. This could be solved by incorporating the lamp with the desk so that, no extension cable is needed to power the lamp. By joining the lamp with the desk surface, a much smaller base is required by the lamp.

Solving these problems by integrating power sockets, USB ports, and lamp incorporated into the desk allows the desk to operate as its own workstation in which the power sockets, USB ports, and lamp can all be connected into one circuit with only one cable that goes out of the back of the desk and connects to the external power source, eliminating many cables that need to be used in the case of using an extension cord. This avoids the unsightliness of the huge clutter of wires when using an extension cord and since the cable comes out of the back of the desk it can be easily hidden to prevent injuries due to tripping.

1.1 Design Situation
The Outdoor Discovery Center (ODC) is an eco-friendly agricultural land located in Jerudong International School (JIS), Brunei. It is used every Monday, Tuesday, and Wednesday by students and Teachers who are a part of the Eco-JIS Committee to work on their projects. The land contains a cabin, known as ODC Hub, in which many projects are conducted by the Eco-JIS committee. The ODC is located in a forest area where transmission lines from the grid are not readily accessible. Brunei Darussalam is located along the equator of the Earth. The country has summer season all year round and it is also very humid. Due to these factors, there is an urgent need for electrical power in the cabin due to several reasons. Firstly, it is very hot during the day and therefore fans are required. Secondly, although, sunlight comes through the windows, it is still dark inside the hub, and therefore lights are required. Thirdly, many students will usually have devices that need to be charged, so charging ports are required. Finally, a workspace is required along with a desk lamp to be used by any member of the Eco-JIS Committee.

As previously mentioned, the power sockets, USB ports, and lamp can all be connected as one circuit with only one cable going out of the desk and connecting to the external power source. Therefore, together, the power sockets, USB ports, and the lamp can either be easily connected to the grid or they can be connected to another means of electricity generation, such a solar power system. This can be useful in remote areas, such as the ODC, where the transmission lines from the grid are not readily accessible.

There are fans and fluorescent tube lights already present in the cabin, however, the main problem is that there is no power source connected to them. The solution to the problem will be to manufacture a desk with in-built sockets, USB ports and a study lamp connected to a solar charge controller and a switchboard which are then connected to solar panels. The solar panels will also be connected to the fans and lights present in the cabin and will be placed on the roof of the cabin.

Although, this product is mainly aimed to be used by individuals at homes, offices, schools, and remote areas such as the ODC, this design situation makes it a perfect scenario for the product to be used by an entire committee.

1.2 Objectives of Research
The objectives of this research are to design, develop, and manufacture a work desk that has the following design specifications:
• Contain a solar power system, with the exception of the battery and solar panels.
• Operate as a sitting desk instead of a standing desk.
Have a splash-resistant surface, to make the product more durable and allow the desk surface to be easily cleaned.
- Contain charging ports.
- Have little or no sharp edges to prevent injuries.
- Have a lamp bright enough to be used as a study lamp.
- Have smooth finish to prevent injuries due to splinters.
- To have a lamp base smaller compared to the ones in the market.
- To function as a self-illuminated desk.
- Contain a storage compartment that is big enough to store equipment for a solar power system and could have extra storage space for the belongings of any students temporarily using the product.

2. Data collection
Students aged 14 - 18 are the end-users of this product. The data is preferred with the 95th percentile of the students because the anthropometric data is needed between a significant age range, meaning if the data from the 1st percentile is used then the desk and overhead lamp will be too small for most users and the product would not be appropriate for use, because only a few students will be able to use it. Similarly, if the data from the 99th percentile is used then the product would be larger than required, and the younger students will not be able to use the product. To add to this, the product will take more time and more materials to be manufactured, thus increasing the cost of manufacturing.

Table 1 shows the anthropometric data that is used to determine the dimensions of the product. Figure 1 shows an illustration of each body segment used in anthropometric measurements.

![Illustration of body segments](image)

**Figure 1.** Illustrative view of body segments for a sitting position.

| Body Segment          | Dimensions (mm) | 14-year-olds | 18-year-olds |
|-----------------------|-----------------|--------------|--------------|
|                       | Males           | Females      | Males        | Females     |
| Crown-buttock height  | 926             | 906          | 994          | 933         |
| Elbow height          | 264             | 278          | 300          | 282         |
| Thigh thickness       | 166             | 166          | 191          | 174         |
| Forward grip reach    | 752             | 727          | 833          | 754         |
The data from Table 1 was obtained from a Belgian website, named Dinbelg [1], and represents the anthropometrics of the Belgian population. Jerudong International School is a British School and consists of a large population of European students. The rest of the students mainly come from Southeast Asian countries and therefore, the dimensions of the desk need to be catered to their anthropometric data. Malaysia consists of three main ethnicities - Malays, Chinese and Indians. In theory, due to the diversity of ethnicities in Malaysia and due to the fact that Malaysia and Brunei are neighboring countries, the anthropometric data of the Malaysian population should be able to represent the anthropometrics of the Southeast Asian students at Jerudong International School. A problem with this is that there is no accessible anthropometric data representing teenagers of ages 14 - 18 years for the Southeast Asian population, including Malaysians. Only the combined data for adults i.e. 18 to 24 year olds [2] can be accessed instead of the data representing only 14-year-olds and only 18-year-olds.

The body growth of most females stops at the age of 18 [3] so anthropometric measurements based on adult females should be the same as the measurements representing only 18-year-old females. This means that data representing adult females [2] can be used to compare the data representing females aged 18 years in Table 1. By comparing the anthropometric data based on Malaysians [2] and Belgians [1], it is noticed that generally the Belgian population has slightly larger body dimensions compared to Malaysians, therefore the dimensions from Table 1 can be used as the main anthropometric data. This is because the maximum body dimensions need to be used in order to determine the minimum dimensions of the product.

3. Initial designs and modelling
This section describes the source of design of the product from its initial stage.

3.1 Concept Ideas
Concept are drawn based on three categories, with each image representing a different category (architecture, nature and design movements), as shown in Figure 2. The writings next to the drawings explain possible material choices and the function of the components in each concept.

![Figure 2. Images of concept designs based on architecture, nature and design movements respectively.](image-url)

3.2 Cardboard Modelling
All concept designs are presented to the client, who comes to a decision of choosing two concept designs based upon factors such as aesthetics, environmental factors, safety, and function. Both of the designs picked by the client are from the same category - design based on architecture. Cardboard models, shown in Figure 3, were produced for both designs. The first model has a small storage compartment and an overhead lamp that would slide to change its position. The second model has a lamp that is able to rotate and change its position in all three axes. According to the client, the design of the desk and the storage compartment from the first model merged with the lamp design in the second model, along with several added storage compartments would produce a design, as shown in Figure 4, that would be suitable for the end-users.
4. First stage of development

Figure 5 displays development in the storage compartment which is divided into two main sections. The front section is for the users to place their belongings such as books, folders, etc. The back section is where all wires coming from the solar panels, batteries, switchboard, charge controller and the lamp will be stored and organized. The circuitry of the USB ports will also be hidden in the back section.

The size of the desk will be 1200 mm in length, 800 mm in width and 800 mm in height. The width of the desk is larger than the width of the desk available in the market to give enough space for the lamp, USB ports and any electronic devices such as speakers or power banks being charged from the USB ports. Figure 6 shows the CAD model of the lamp base. The design of the base is produced after many analyzing many different ideas. This real size of this base is much smaller compared to a standard desk lamp base therefore, it will take up little space on the desk. The base will be bolted onto the desk to prevent it from toppling over and will be able to rotate and change position in all three axes.

5. Analysis of different types of lighting

Research was conducted on the types of lighting in order to determine the most appropriate lighting to be used in the desk lamp. The following three main forms of artificial lighting - incandescent bulbs, compact fluorescent light bulbs, and light-emitting diodes, were compared and analyzed:

- Incandescent bulbs contain a high-temperature tungsten filament that emits visible light along with infrared waves. Only 3% - 8% of the energy is converted into visible light, while the rest is dissipated as heat. The life of each bulb is approximately 1000 hours. Additionally, incandescent
bulbs are fragile, difficult to recycle, are sensitive to voltage fluctuations. These bulbs flicker and usually cause eye strains.

- Compact fluorescent light (CFL) bulbs use electrons emitted from cathodes to excite mercury vapor that emits ultraviolet light which causes the phosphors in the bulb to glow, producing visible light [4]. 15%-20% of the total energy is converted into visible light. The lifespan of each bulb is about 8000 hours [5]. These bulbs are also fragile, sensitive to voltage fluctuations, cause eye strains and headaches due to fluctuations of visible light [6], and need special handling and recycling due to potential mercury vapor leaks.

- A light-emitting diode (LED) are semiconductors that emit light using the principle of electroluminescence [7]. Light is emitted when current passes through the diode. 90%-99% of the total energy is converted into visible light, while the remaining is dissipated as heat. The lifespan of each light-emitting diode is 25000 - 50000 hours [5]. LEDs are easy to recycle and are rugged and robust. Additionally, these types of lights do not flicker and, therefore, do not cause headaches and eye strains in the same way incandescent and CFL bulbs do.

From the above comparison, the best choice of lighting is to use LEDs because of its long lifespan, durability and electrical savings. Furthermore, LED lights come in a variety of different forms that have different shapes, sizes, light colours, and other characteristics. These diodes are produced in forms such as bulbs, tubes, and strips. This provides flexibility to design the lamp head in any shape or size.

For the lamp to have a plain, modern, and minimalist look, the head of the lamp needs to be small in size and have a basic geometric shape such as a rectangle or circle. Using an LED bulb will provide enough light, but it will make the lamp head heavy and large in size and, therefore, will decrease the stability of the overall lamp. The use of LED strip lights allows the lamp head to be small and lightweight, however, strip lights that provide enough brightness to study are very expensive compared to other options available in the market. A cost-effective and better alternative is to use LED arrays as they come in a large variety of the number of diodes in each array, more diodes meaning more brightness. The arrays used in the production of the lamp each has a size of 6 x 3 light-emitting diodes and emit light with high brightness. These arrays require 12 Volts to operate at the maximum brightness, which is the same amount of voltage required by the USB hub integrated into the desk surface.

6. Life-size modelling

Testing was required to determine the number of LED arrays needed to provide enough lighting for the lamp to operate as a task lamp. First, each array was tested while connected to a 12 Volt power supply, and then they were placed together into a cardboard model of the lamp head, as shown in Figure 7.

The initial results of the testing showed that each array illuminated a 700 mm x 500 mm space on a surface very well, however, the light from the array was too hard on the eyes and needed a diffuser to soften and spread the light. The use of diffuser slightly decreased the overall brightness of the light shining on the surface. Now it illuminated a 400 mm x 400 mm space well, which means that a total of six LED arrays will perfectly light up the 1200 mm by 800 mm desk if the lamp head was divided into having the LED arrays placed in two rows, with each row consisting of three arrays.
7. Input from the end-user

In order to know more about the likes of the end-users, a questionnaire was created to be answered by the members of the Eco-JIS committee, which will be the users of the final product. The results of the questionnaire are as follows:

- Potential users liked the aesthetics of dark-colored natural wood out of different shades of wood surfaces.
- Neutral white light was preferred over cool or warm white light.
- The favorite design movement selected was Modernism.
- The favorite type of finishing chosen was stain.
- Potential users want the study lamp to be overhead and movable.

8. Final stage of development

Shelving units are added to the side of the desk to store the PWM solar charge controllers and the switchboard. These should not be stored at the storage compartments at the back, where they will be hidden, as they need to be regularly accessed. Modifications are made in the overall design for wire management so that minimal wires could be seen, shown in. Figure 8 shows an illustration of how cables from the solar power system will be organized while remaining hidden.

Figure 9 shows the final models of the lamp spine. The spine was designed in a way that allows it to allow the lamp head to move freely in any position. The spines can be set so that the lamp can be set at a short height, a medium height, and a tall height. It is also able to set the light focused at a specific area of the surface. Figure 10 shows the final rendered CAD model of the product.
9. Manufacturing

The product was fabricated using several manufacturing processes including CNC routing, laser cutting, 3D printing and MIG welding. The metallic frame of the desk was joined together using MIG welding and the welds were made smooth using the process of metal grinding. Black spray paint was applied to the finished metal frame. The desk surface, shelving units, and storage compartments were made by CNC routing plywood, which was then partially painted and partially laminated with a dark wooden pattern of laminate. The plywood was joined together using PVA glue. The lamp was manufactured by laser cutting laserply which was stained with a dark brown colour to match the laminate used on the desk surface. The laser-cut parts of the lamp were glued together using PVA glue. Layers of polycrylic were applied to the stained laserply in order to seal the surface of the wood, making it resistant to damage caused by water and insects and to give the wood a glossy look. Contact adhesive was used to join the laminate to the plywood desk surface.

10. Final product

![Figure 11. Pictures of the final product.](image)
Figure 11 presents pictures of the final product. In terms of appearance, the color scheme is simple, making the product look cohesive in design. The default size of the lamp is suitable, but if required, the size can be tailored to the user’s preferences. The second image in Figure 11 shows the product being used in darkness and it can be seen that the adjustable lighting provides enough lighting to the entire desk surface. The textures used on the product are smooth and glossy which adds to the attractive look. The overall finishing is admirable, as all the materials in both, the desk and lamp used are smooth and polished, and the paint applied is coated evenly. The small base of the lamp is bolted onto the desk and prevents the lamp from being toppled over. The base is small enough to take very little space on the desk surface. Users can change the direction of the lamp by rotating the base through a semi-circular disk. LED lights are used instead of incandescent bulbs meaning no there are little to no heat problems since incandescent bulbs emit a large amount of heat. The desk consists of dedicated storage sections for PMW solar meters and switchboards. The level directly beneath the top is segmented using a jigsaw structure to act as compartments for various apparatuses such as books and stationery. The compartments behind this layer manage cables in an organized way. The desk supports a twin solar charging system. Two separate charging systems are arranged (supplying separate batteries/output circuits). This allows maximum redundancy for component failure.

Additionally, this desk is very spacious thus allowing any user to place multiple objects on it such as large folders, books, and stationery without making the desk look cramped. The lighting is soft and does very well to illuminate. The materials were carefully chosen while considering both cost and function. Readily available materials were used to keep the costs of manufacture to a minimum.

When comparing the initial design specifications and the final product, all design specifications have been fully met except for the specification stating “have little or no sharp edges”. Although all sharp edges were smoothed to prevent edges, it would be better in terms of safety and aesthetics for the desk surface to have no edges by making the edges curved. An implementation of this is shown in Figure 12.

11. Feedback from client
This desk is no doubt innovative and highly efficient with its eco-friendly approach in generating electricity using solar panels. More impressively, the LED lamp combined with the easily accessible USB ports allow for a comfortable and productive workspace as I personally often have issues with poor lighting while doing work on my desk at home and the USB ports allows me to easily charge my devices without any hassle. Additionally, this desk is very spacious thus allowing any user to place multiple objects on it such as large folders, books, and stationery without making the desk look cramped. In terms of aesthetics, the desk has a modern and clean look which is very pleasing. The product can be improved by making the desk adjustable by height as this would aid users that have back pain and would especially help the older demographic. But overall, the product is superb.

12. Conclusion
In conclusion, from the satisfaction of the end-users and client, it is clear that the product fulfils its intended function well while maintaining an aesthetically pleasing appearance with consideration of safety and environment. The lamp and desk are both comfortable and ergonomic. The proportions are spot-on for its use because increasing the product’s scale would make the lamp too clunky and overbearing, and decreasing the product’s scale would make the lamp more inefficient in lighting, making it look cheaper. Human factors have been considered during design as the lamp does not detract from the customer’s field of vision during study.

Overall, the product is designed and fabricated to a high standard and it is hoped that it would be a popular choice for consumers to use as a work desk at their homes, offices, and schools.
13. Recommendations for future work
To improve this product, the following changes can be made:

- Due to advancements in technology, more and more phones are manufactured with the capability of wireless charging, therefore, incorporate a wireless charger into the desk surface for charging phones.
- Place the switch of the lamp on the base of the lamp instead of having the switch on the lamp head.
- Use a single large LED array instead of several small ones, therefore, decreasing the amount of wires and allowing the lamp head to be smaller and thinner in size.
- To improve aesthetics and safety of the desk, medium-density fibreboard (MDF) can be used as the desk surface, and the MDF towards the edges can be bent into the edge of the lower wooden surface by making the MDF flexible, as shown in Figure 12. MDF can be made flexible using parallel saw cuts on one face allowing the wood to bend [8].

Figure 12. CAD drawing of desk surface with curved edges.

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