Reconfigurable and Ergonomic Smart Desk – An EPS@ISEP 2021 Project

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ABSTRACT

The European Project Semester (EPS) offered by the Instituto Superior de Engenharia do Porto (ISEP) provides engineering, business and product design undergraduates with a project-based learning experience in a multicultural and multidisciplinary teamwork environment. This paper reports the research and development of a reconfigurable and ergonomic three-level desk, for people who live in small spaces, by a multicultural and multidisciplinary team of five students. The main objective of the project was to integrate ethics- and sustainability-driven practices in the design, simulation and test an ergonomic, transformable desk. The FREE desk proposal aims to create a comfortable and dynamic working environment for people while providing a transformable space for different daily activities. This goal was pursued by designing a reconfigurable product, a smart desk that offers the user three levels of adjustability: bench level, sitting desk level, and standing desk level. The desk includes a folding light-sensor lamp into the table top and an integrated battery, in order to create a proper working space. The selected materials have a low environmental impact. The solution comes with different options regarding the table top lifting mechanism. This paper describes the state-of-the-art research, the ethics, sustainability, and marketing analyses, the design and simulation of the FREE desk as well as the obtained results.

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CCS CONCEPTS

• **Social and professional topics** → Professional topics; Computing education; Computing education programs; Computational science and engineering education; Professional topics; Computing industry; Sustainability; • **Applied computing** → Education; Collaborative learning.

KEYWORDS

Engineering education, Project-based learning, Multicultural and multidisciplinary teamwork, European Project Semester, Reconfigurable and ergonomic smart furniture, Working from home, Innovative solutions

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1 INTRODUCTION

The European Project Semester (EPS) was created by Arvid Andersen in 1995 as an international exchange program to train engineering undergraduates to behave and think internationally. To foster research, analytical, and organizational skills, it uses project-based learning and multicultural, multidisciplinary teamwork. Since 2011, EPS is delivered by the Instituto Superior de Engenharia do Porto (ISEP) of the Polytechnic of Porto [1].

COVID-19 pandemic impacted professional and personal environments worldwide, including aspects like sleep quality, concentration capacity, stress level, and a more sedentary behaviour [2]. Since work from home came to stay, there is a need to redefine its model. This project contributes with a sit-to-stand desk that enables the user to define the position which allows him/her to best focus and be comfortable. The FREE product starts off as a bench, providing usability for daily activities before or after working. It can be transformed into a sitting desk or a standing desk. The objective is to provide a simple but functional and ergonomic design.

FREE is a product designed by a team of five students during the spring of 2021. The group is composed of people from various countries (Belgium, Romania, Macedonia and Poland), as well as different fields of study (computer science, product design, mechanical engineering, business and project management) from bachelor's and master's degrees. EPS provides the team with a learning environment to implement and improve the project-specific skills. Design, modelling, and testing of a practical, ethically and sustainably aligned, ergonomic and reconfigurable furniture were among the open-ended project requirements. The cost of the materials and components required to build a prototype should not exceed 100 € .

This paper reports the creation of an innovative, reconfigurable three-level flexible desk/bench aimed for people who live in small spaces. Therefore, FREE stands for furniture, reconfigurable and ergonomic. The goal of the FREE product is to provide a dynamic and comfortable environment for working and living. The ergonomic reconfigurable product is conceived to facilitate the displacement of the desk's table top from bench to sitting and standing desk. Furthermore, to enable productivity, autonomy and comfort, the table top includes an integrated lamp, battery, electricity sockets and communication ports, ensuring a cleaner, uncluttered working environment.

This paper scaffolds the development of FREE three-level adjustable desk EPS project, starting by presenting the state-of-the-art research and background, explaining the design concepts, followed by the simulation, and predicted tests. Finally, the discussion and conclusions regarding the product FREE are pointed out.

2 PRELIMINARY STUDIES

These studies focused on related solutions, ethics, marketing and sustainability. Transformable and ergonomic furniture solutions were analysed considering the COVID-19 pandemic's global impact on working habits. Due to sanitary restrictions, many workers were forced to adopt the working-from-home model. However, this model affects people negatively, leading to poor sleep quality and concentration, causing mood disturbances and stress, and increasing sedentary behaviour [9]. Nevertheless, recent studies have shown that most of the workforce considers the future of work to be a hybrid model where employees work from the office and from home [8]. This new work paradigm requires innovative designs to create a comfortable, dynamic, adaptive working environment at home, one that can be easily reconverted for different daily activities.

2.1 Related Solutions

The design of transformable furniture must involve at least two forms of appearance and function [3]. By having multiple functions, the furniture serves people who have little space. This state-of-the-art of transformable furniture designs focused mainly on adjustable desks. Table 1 presents the studied products that provide transformability and ergonomics.

Ergonomics is a scientific discipline that studies the relationships between humans and other system components [4]. A good ergonomic design reduces incompatibilities between humans and their working space, creating a perfect working environment. Ergonomic furniture has the ability to adapt to the individual requirements of the user to ensure good posture. It is specifically designed to ensure maximum comfort and overall wellness of the user. Ergonomic furniture is highly recommended for the home and work offices where one tends to spend a lot of time sitting [5–7]. Considering all the research done and the present demands, a new solution for a reconfigurable desk was devised. This solution and the design concepts embraced are the core of the following sections.

2.2 Ethics

The team decided to embrace ethic values and adopt a deontological conduct. The view of the product and purpose is influenced by the company's values, strategies, and actions, following the law and technical standards. As far as the engineering code of ethics, the project must adhere to these guidelines to create a professional and trustworthy brand for the product. The product's design and development must comply with public safety, health, and welfare. To strengthen the relation between user and product it is essential to adopt a sustainable strategy and adhere to a code of ethics from the beginning of the design process until the product is distributed. In each phase of this process, engineering, marketing, sales, and the environment, must be considered. When it comes to the environment, the main goal was to create a sustainable and eco-friendly product, by reducing plastic use and reusing the packaging material. The team concentrated on choosing a recyclable packaging material

Table 1: Ergonomic and transformable products

Name	Features	Price (€)
Propr Office	electrical – adjustable height desk, electric lifters, durable and commercial quality laminate top (easy to clean and disinfect)	420-585
Jaswig StandUp Nomad	manually adjustable – tool-free assembly in under 15 min, easy to move around, ergonomic footrest, storage room, different height settings	250-420
Mateo Goods Sit-stand Desk	electrical – adjustable height desk, integrated wire management, 3 power modules with Universal Serial Bus (USB) charging ports	1165
Bekant Desk	electrical – adjustable height desk, cable management net(keep desk tidy), deep table top, table top is wear-resistant, stain-resistant and easy to keep clean	449
Yaasa Desk	electrical – adjustable height desk, Hand switch beneath table top, lightweight	498
Vivo Desk	electrical – adjustable height desk, built in cable management, memory pre-sets, timer to stand up	333
Allcam Desk	electrical – adjustable height desk, 2 button remote, assembly in 10 min	230
PrimeCables Desk	electrical – adjustable height desk, memory pre-sets, adjustable width, can bear a 124 kg load, not very stable	270

to reduce its environmental footprint. The FREE desk is a product that addresses all of these concerns, providing excellent usability and in adherence to applicable directives, legislation, and health and safety regulations.

2.3 Marketing

To server a wider population and create a good sales strategy, the team analysed the current market regarding desks and furniture in general. The FREE desk brand was defined based on the characteristics of the product, and strategic objectives, like developing a profitable business model and building a good relationship with customers, to ensure a good follow-up. The logo shown in Figure 1 illustrates the name of the brand and its focus. During the demographic analysis, the primary target market was identified – the population working from home or from the office. Transparency is essential. The FREE desk expects to establish its presence in the market through a dedicated website and social media channels (Facebook, LinkedIn, Instagram). By actively posting materials and using paid advertising, bigger audiences will be reached. The product will differentiate itself from the competition by using sustainable materials, offering innovative design, and promoting the three-level adjustable desk concept.

2.4 Sustainability

Sustainability means meeting current needs without compromising the ability of future generations to meet their own [10]. To achieve this goal, the team focused on easy repair, disassembly, and recyclability. The FREE desk will be made of two recyclable materials: solid maple wood and aluminium. This choice of materials considered also the reduction of the amount of volatile organic compounds (VOC) and contributes to the durability of the desk, which distinguishes it from the fast furniture model. The maple wood must be certified by the Forest Stewardship Council (FSC) and/or the Programme for the Endorsement of Forest Certification (PEFC) to ensure it was sustainably sourced. The user will assemble the product at home, allowing the different wooden planks to be flat-packed. This makes shipping more efficient. The integrated lamp is made of light-emitting diodes (LED), which are power efficient and last longer. The desk will be treated with water-based finishes containing significantly fewer VOC than conventional solvent-based finishes. This means that less solvent can evaporate into the home environment, which is beneficial both for the health of the user and the environment.

3 PROPOSED SOLUTION

The reconfigurable and ergonomic desk solution involved the definition of the concept, the design of the FREE desk and its packaging and, finally, the development of a proof-of-concept prototype.

3.1 Concept

The FREE team developed a reconfigurable desk for people who live in a small space and need to reconfigure their furniture for multiple purposes. The desk is designed to offer the user three levels of adjustability: bench, sitting desk and standing desk (Figure 1).

For adjusting the table top level, three types of mechanisms were selected. The legs, which are integrated into two boxes, are made from the same material as the table top. The boxes provide storage space. The right box is a one door cabinet and the left box is a set of three drawers. Both boxes are naturally ventilated. The table top creates a dynamic and autonomous workplace that features an integrated battery and an auto sensor lamp. In terms of ergonomics, the transformability functions of the table top as a sitting desk support an upright and straight posture of the users. Another key concept of the product is the adoption of the do it yourself (DIY) method. The FREE desk is sent partially assembled, with instructions to help the user set it up properly. This assembly concept ensures easy and compact transport. The right box has a door with 2 aluminium hinges and weighs 10 kg, whereas the left box has 3 drawers held by 6 aluminium drawer slides and weighs 11 kg. The table top dimensions are 60 cm x 120 cm, and it can withstand a maximum load of 90 kg. The battery is integrated on the bottom side. The lamp is integrated into the table top and can slide in and out with ease.

Figure 1: The concept model and logo of the FREE desk.

Figure 2: Design of the desk boxes.

Figure 3: Levels of adjustability and integrated lamp.

3.2 Specifications

To provide a proper working environment, the team estimated a table top of at least 0.70 m^2 for one person. Based on this area, the desk dimensions were defined. The minimum height of the transformable mechanism (bench level) is 53 cm for the electrical mechanism and 58 cm for the crank lifting mechanism; the maximum height (standing desk level) is 120 cm for the electrical mechanism and 110 cm for the crank lifting mechanism.

The height of the intermediate-level (sitting desk level) is adjustable and can be decided by the user. The mechanism is manufactured from aluminium, having a total weight of 18 kg, including the legs. Boxes and top are from solid maple wood. Figure 2 presents the boxes with 50 cm height, 60 cm length and 30 cm width.

3.3 Design

The structure of the FREE desk consists of the two legs, coupled with the lifting mechanism, two boxes, and the table top. The desk can be configured as a bench, a sitting desk, and a standing desk. When in bench position, a compact version of the product is created. In this position, the desk maintains all other features, the storage space provided by the boxes, and the integrated battery. The lamp integrated into the table top slides inside to create a flat surface that serves as seat. When activating the lifting mechanism, the bench transforms into a sitting desk or standing desk. In the next section, the lifting mechanisms are presented. Figure 3 displays the three levels of adjustability, the boxes, the table top, crank system and the integrated lamp.

Transformable Mechanism. The team analysed five options for the three-level lifting mechanism:

- Electrical – The mechanism consists of one motor to lift the two legs of the desk, ranging from 50 cm to 120 cm. It is quiet (under 50 dB) and works with standard 230 V electric power. This premium version is reconfigurable, strong, easy and comfortable to use.
- Crank – The crank is located in a corner under the table top and moves at a rate of 30 mm per turn of handle, adjusting from bench to sitting in 6-7 turns, and from sitting to standing in 12 turns, requiring 19 handle turns to get from the bench position to the standing desk. The team explored this mechanism in order to offer a reconfigurable, easy to use alternative at an intermediate price. The dimension of the commercial extension mechanism found limits the height the table top can reach. In this case, for the bench level, the height is 58 cm and for the standing desk, the table top can reach a maximum of 110 cm.
- Slider with Lock-Pin – This mechanism, which uses spring button clips to adjust height, provides reconfigurability at the lowest price. The advantage is that the product can be configured in the three positions at a low cost of production. The main disadvantage is the discomfort the reconfiguration may cause the user.
- Pneumatic System – Pneumatic lifting mechanism incorporates a hollow cylinder and piston. An external motor or pump moves the piston within the cylinder, increasing the internal air pressure and causing the cylinder to move along the axis of the piston. This mechanism lifts very heavy loads with little force, has a price between electric and crank lifting mechanisms, but the solutions found have limited height adjustability.
- Scissor – The scissor mechanism extends by applying pressure to the outside of a set of supports located at one end of the mechanism, elongating the crossing pattern. While it is a reliable, simple, smooth vertical movement, low cost mechanism, it is quite heavy and aesthetically unpleasant.

The team decided to create three versions of the product corresponding to the electrical (premium), crank (standard) and slider with lock-pin (basic) lifting mechanisms.

Autonomous Integrations. FREE desk offers automatic lighting and power autonomy based on an integrated battery through a small electronic circuit with an Arduino, a relay and a light sensor as main components.

- Battery – Desk power autonomy is ideal for places without nearby power sockets. The integrated battery, which powers the integrated LED lamp and the multiple device ports, recharges easily overnight, via a standard USB interface with the help of a transformer.
- Light Sensor – A light dependent resistor (LDR) detects the intensity of light. The LDR offers low/high resistance in presence of high/low intensity of light, displaying a voltage drop directly proportional to the light intensity. The Arduino then translates this analogue voltage into a 0 to 1023 digital value, using its built-in analogue-to-digital converter. The translated digital values will be in the range of 800-1023 when there is light. When the light intensity is low, the Arduino activates a relay to turns the LED lamp on.

Figure 4: Prototype.

3.4 Packaging

An eco-friendly packaging has to be cost-effective, support ecological health, be ethically correct and have a wider range of usage, such as repurposing. The team considered the send-box-back solution, where customers fill the box with used electronic devices, batteries, and send the box back. From there, the company will navigate the package to appropriate services. Also, the empty space inside the transportation box will be limited by properly placing the components on top of each other, adjusting the sizes of parts to the packing order. The small pieces of cardboard can be used to compartmentalize the inside of drawers and boxes. One main objective of this product is to provide proper storage space, so the team included DIY instructions for the user to reuse the cardboard. Another aspect that makes the packaging sustainable is the limited use of plastic bags and foils. The usual plastic protective foil is replaced with a bubble wrap made of granulate, which is 100 % recyclable and biodegradable. Also, plastic string pouches for mini tool kits and screws are replaced with compostable versions made from a combination of bio-based and synthetic polymer materials.

3.5 Prototype

The team made a prototype to illustrate the concept with a 100 € budget. The team was unable to use the materials selected for the proposed solution. Instead, concentrated on reusing and integrating materials, making the prototype as eco-friendly as possible. The materials used in the prototype were an old desk for the structure and table top, polyvinyl chloride (PVC) for the boxes, a LED lamp, and an external battery. An Arduino circuit was built to test the sensor-lamp concept. The scope was to analyse the comfort of the desk and its ergonomic properties by transforming it. The boxes were built to show its usability as storage and illustrate the work from home desk concept. Figure 4 displays the assembled prototype in the sitting and standing levels.

4 SIMULATION

Using simulation software, the team ensured that the FREE desk withstands the expected loads, both in the bench and desk position. Since the lifting mechanisms were tested by the manufacturers, the team tested the pressure the table top withstands when used as a bench. After several iterations, the final results were obtained with a load of approximately 1800 N applied in the middle of the table, a 2.5 cm thickness table top and a safety factor of 3.5, resulting in a

table top displacement of 3.4 mm and a 6 MPa equivalent von Mises stress.

5 DISCUSSION

The team identified two main limitations regarding the:

- Transformable mechanism – The FREE Desk is presented with three lifting mechanisms, price and ease of use: electrical, crank lifting, and sliding with lock-pin. The premium electrical version provides all functionalities with the highest usability. The standard crank lifting version makes the bench level higher (58 cm instead of 53 cm) and the standing desk lower compared with the designed model (110 cm instead of 120 cm). The basic sliding mechanism with lock-pin version provides all the functionalities at the expense of muscle power.
- Prototype – Since the prototype did not use the selected materials, the team was unable to check the functionality of the three lifting mechanisms and the bench level. Nevertheless, it was able to test the advantages of the transformability concept and the limited ergonomics characteristics provided by two levels of adjustability included in the prototype: sitting and standing desk (Figure 4). The transformability proved to be ergonomic and the boxes their usability as storage space, making the overall working environment look like a space for productive work. The sensor-lamp concept, with the light sensor, LED lamp, and the battery in the prototype, proved to be important to create an autonomous dynamic working environment.

6 CONCLUSION

In EPS@ISEP, one semester of teamwork produces outcomes at both project and personal levels. The latter implies personal transformation and, for that reason, is the most important.

The team set out to test the feasibility of developing a successful, ethical and sustainable business around an ergonomic adjustable desk for people who live in small spaces. To this end, the team created: (*i*) a marketing plan to promote the product and target people and organizations; and a (*ii*) detailed business plan considering logistics, costs, supplies, and the target consumers. Sustainability and ethics concerns guided the decision making process of the team throughout the design and prototype development stages. Although the desk was not produced, it was possible to explore and partially test the concept by building a prototype. As further steps, the team aims to further develop the desk while striving to create a final prototype, this time with the original materials. Moreover, the team would like to investigate potential operational problems to prevent future risks and implement preventive countermeasures.

Regarding this learning experience, the team members shared the following opinions:

- "When I have entered the EPS@ISEP program, I knew that it was, above all, an opportunity to get out of my comfort zone, to work with a team in a foreign language while combining our different fields of study and to live and travel in a beautiful city and country. At the beginning, the COVID-19 situation only allowed online work. From April onwards, the team had weekly meetings at the university. This experience teaches you on-the-go and relies on one's willingness and motivation to develop at a personal and professional level. Here I discovered new capabilities namely how to adjust to a team that I had never met before." – Gabriel.
- "I think this EPS experience was very useful, both on a personal and professional level. During the course of this semester, we learned to work with each member's strengths and weaknesses and gained knowledge in unfamiliar fields. Working together in an international team is a challenge, given the cultural and educational differences. The team overcame these challenges, even in the midst of the pandemic. The experience of exploring Portugal and meeting new people was an incredible and unforgettable one." – Anastasia.
- "The European Project semester was totally different from my usual projects. It was an amazing opportunity to work together with students from different study backgrounds and different nationalities. I am happy that I had this opportunity and I thank my colleagues and the teachers for all the lessons taught." – Silvia.
- "It was a very hard and challenging experience for me as I was unable to join my teammates in Porto. Even though we didn't meet in person, my team was a valuable, hardworking and helpful group of people. Together, we overcame remote miscommunications, and everyone contributed to the project. I hope the pandemic will be forgotten in a short time and I'll have an opportunity to visit Porto and make up for the lost time." – Marcel.
- "Working with individuals of various countries and backgrounds at EPS was a fantastic experience for me. I learnt a lot about cooperation, work consistency, and product development, and my present field of expertise has considerably increased. To add to that, I feel that EPS not only aided me in expanding my academic and practical skills, but also introduced me to new people." – Nicola.

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