

## 3D CAD AND 3D PRINTING-BASED PRODUCT DESIGN: CASE STUDY OF AN ARMCHAIR

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### Abstract

Digital design is an efficient way of implementing furniture concepts. Advanced tools for rendering have a considerable effect on increasing their visibility via the use of sophisticated software that simulates the final appearance of furniture using appropriate textures, colors and environment. Although color plays an important role in the product's promotion, additional use of textures creates a more realistic appearance. The goal of this study was to develop an armchair using digital designing and physical prototyping. A variety of methodological and digital tools have been used to create a unique product, with effective application of 3D CAD and 3D printing technology in the design of an armchair. The present paper deals with the design of an armchair for children. Anthropometric shapes were used in the design process, thus digital sketches assisted in digitizing the armchair using an advanced Computer Aided Design (CAD) system. These models were enriched with colors and textures in order to convey the design concept, while providing a realistic view of the final solution. The prototype was built based on the CAD models created, in order to verify the incorporated specifications. Combining not only the effective geometry of the armchair but also its colorful appearance, a customized product for children was developed. Both the methodological and technological tools used supported the creative approach to the design of the armchair presented.

**Keywords:** *sculpting, CAD, product design, prototyping, 3D printing.*

### Introduction

Digital 3D design technologies dominate product development. The needs of both customers and enterprises are served by professionals that combine methodological and technological tools in product and furniture design. A great deal of resources can be saved if all the available tools are used at the early stages of the design cycle i.e. the mind map (a conceptual map that gives the designer the opportunity to think out of the box), 2D

digital sketching (offers the opportunity to be creative in two dimensions and explore a number of design directions), CAD (Computer Aided Design, digitize the 2D sketched concepts in 3D models), rendering (creating real life-like digital appearance of the designed product), prototyping (with the use of a prototype technique the final concept is examined if meets all the requirements set, 3D printing technology offers additional advantages at this stage).

The longer the analysis and development process of the new product, the fewer errors the final product incorporates. For all industries, every error discovered later during the product development cycle results in higher cost for corrective actions. This is the basis for using all the available methodological and technological tools with the aim of avoiding making mistakes or spotting them as soon as possible during the design cycle.

Castellucci et al. points out that all the pieces of furniture should follow a series of guidelines based on anthropometrics and ergonomic principles, i.e. front tilted desks, high seat chairs. As a result, chairs can improve posture, academic performance and attention in the classroom (Castellucci et al., 2017). Jiang et al. dealt with young users and their preferences. They refer to the impact and choice of color by younger generations. Adults usually choose dark furniture while children's preferences include particular interest in white ones. In more detail, girls prefer red and white for chair colors, while boys prefer green, blue and yellow (Jiang et al., 2020). Sraiheen and Dalgin in their work on the importance of color, state that it can affect the consumer's overall perception of a product. Color is not perceived the same by men, women, and their country of origin. People emphasize color in specific product categories in different ways. Sraiheen and Dalgin provided a solid basis about the importance of color in clothes, shoes, and home related product colors. They even proved that a number of differences presented were related to genders. Men emphasized more on the digital colors they use, while women showed strong preferences to the colors and shades, they wear (Sraiheen, Dalgin, 2018). With respect to the combination and the colors importance, Lucius and Fuad stated that the color wheel can support and enrich the available data. This is achieved through the attractiveness created by the graphs and combinations that are proposed. Some of these are complementary, which consist of two colors that are opposite to each other on the color wheel. They also emphasize other harmonious combinations, i.e. equilateral triangle shape on the color wheel. The equilateral triangle on the color wheel can give combinations such as yellow, red and blue, which are the most powerful triad of colors and are called fundamentals (Lucius, Fuad, 2017). An alternative approach to product design is proposed by Manavis et al.,

when presenting the importance of product inspiration from nature. In this research, it is argued that nature is one of the oldest design methodologies, developing alternative illustrative examples inspired by nature thus providing new opportunities in marketing and product promotion. It is even argued that computational design tools can be used for designing highly complex geometries that are inspired by nature (Manavis et al., 2019).

People often emphasize the packaging and the way that it can attract the customers' attention. An unusual work for a toothpaste package was proposed by Malea et al. In this research, toothpaste packaging was developed, based on anthropocentric design and environmentally friendly principles. The development of the packaging was supported by different tools i.e. mind map, 2D digital sketches, 3D CAD modeling, rendering, prototyping (Malea et al., 2020). Ligka et al. developed a wearable headband for increased aesthetic purposes. It was developed based on both parametric design and biomimetic principles. Parametric design offers the opportunity to provide a great deal of alternatives and can satisfy different customer demands. At the same time, the product is customized for each user and can be 3D printed for prototyping or fabrication purposes (Ligka et al., 2024). In the present paper, a children's armchair was perceived and developed using a series of methodological tools, i.e. mind map, 2D digital sketching and technological media i.e. 3D CAD system for modeling and rendering purposes, 3D printing facility. The main idea was to have an armchair that can attract children's attention and be comfortable for use based on ergonomics.

### **Proposed methodology**

In this study, a nature inspired armchair for children was proposed with an aim to combine biomimicry with ergonomic and a customer centered approach. The frame of the armchair was inspired by the branches of the trees and takes advantage of the familiarity that children have with them. Further to the product's definition and the initial 2D digital sketches, 3D CAD models were designed. The armchair was initially rendered with the appropriate colors and textures and then prototyped by a 3D printing facility (Figure 1). The design thinking principles were incorporated in this study by using methodological and technological tools together with the early involvement of the users. The users were able to provide an early evaluation of the proposed armchair design via the 3D printing prototype produced. At the same time, they felt satisfaction in contributing to the design process.

| Workflow schematic   |                         |                                   |
|----------------------|-------------------------|-----------------------------------|
| Product Category     | Interior Design Product | Children's Armchair               |
| Design Concept       | Inspiration             | Natural colors & ergonomic design |
| Implementation Tools | CAD                     | Visualization & 3D CAD Modelling  |
| 3D Printing          |                         |                                   |

Figure 1. Workflow schematic to create products

## Case study development

The first methodological tool used was the mind map. Through the mind map, the scope of solutions is expanded. In the case of the children's armchair, the most unusual ideas/proposals were promoted i.e. the imitation of the structure of tree branches and the balance of colors (Figure 2).

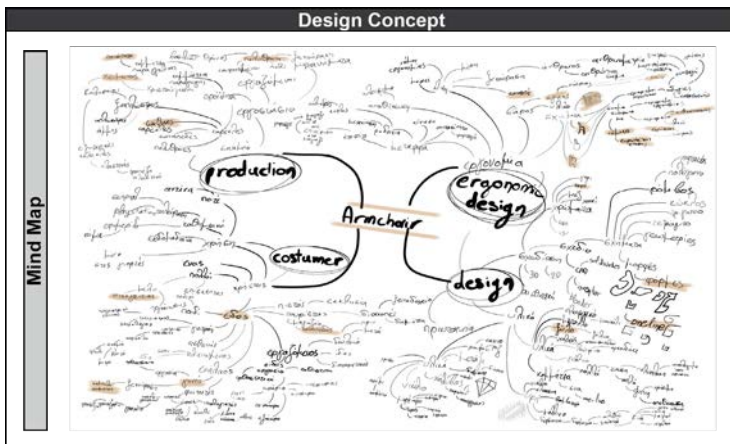


Figure 2. Mind map used for increased inspiration

Based on these ideas a great deal of 2D digital sketches were developed and captured the tree branch concept defined previously. A four-step approach was followed with different levels of sketching details (Figure 3):

- Process sketches: the inspiration used natural shapes and various seat geometries, i.e. car seats, school chairs, office chairs, children's seats, lounge/medical chairs, armchairs.
- Ideation sketches: a great number of chairs and armchairs shapes were examined.

- Explanatory sketches: A selection process was used to finalize the proposal in 2D sketched form and more detailed appearance of the proposed design was achieved.
- Persuasive sketches: a final sketch was created that captured the proposed armchair geometry and concept. It has included textures and colors.

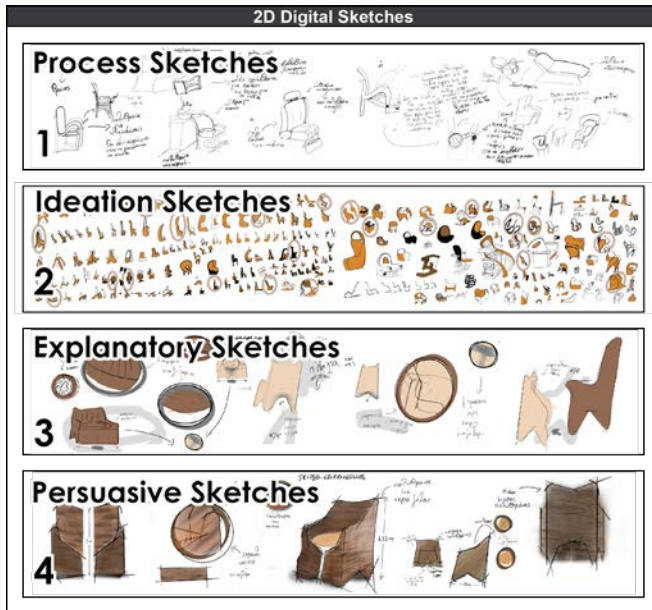


Figure 3. Sketching development in 4 stages

A 3D CAD modelling technique supported by sculpting was necessary due to the complexity of the geometry proposed. The mesh of the created geometry demanded a lot of attention in order to mimic the texture of a tree. Blender™ CAD software was used in this case because it is a powerful digital tool that at the same time is free and open accessed. Complex geometries can be modeled and provide high quality digital models for prototyping. During the armchair design anthropometric data and dimensions were taken into consideration, while at the same time filleting the geometry was necessary in order to avoid sharp corners for safety reasons. The main geometry of the armchair was a combination of a stool surrounded by a frame that

looked like a tree geometry. The tree geometry was modeled using CAD based sculpting techniques that provide a way to model unusual geometries. Blender™ has a specific module for this modelling approach.



Figure 4. Design development using digital sculpting techniques

In more details, 3D CAD modeling resulted in shaping the armchair to look like tree with the appropriate branches, while the stool was positioned inside the surrounding geometry for easy transportation and use. The use of the appropriate color combinations was made based on the wheel of colors in order to attract the attention of the children. So, combining blue with shades of red, green with shades of red, and shades of blue with white, resulted in attractive selections from the user’s point of view (Figure 5).

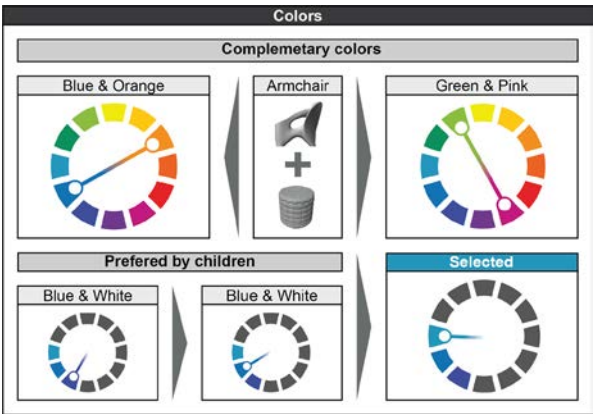


Figure 5. Color matches the rules and preferences of children

Figure 6 depicts the 3D CAD modeling workflow, and the three alternative colors used to satisfy the variety of users. The results present a detachable armchair inspired by the shape of trees. The shades were related to the preferences of children and the rules of the color wheel.

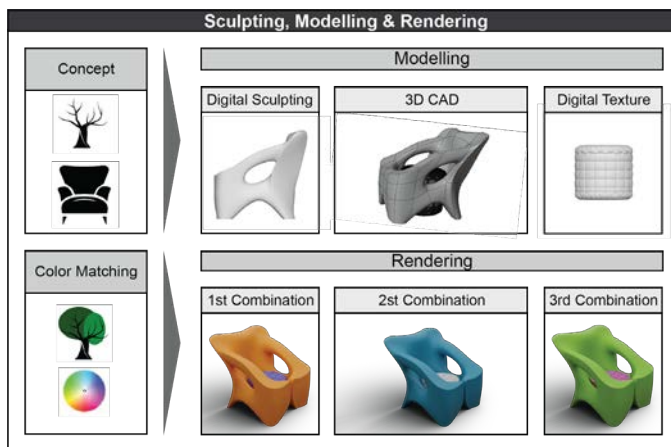


Figure 6. From concept to 3D CAD modeling

For the digital 3D model to be 3D printed for prototyping purposes, a series of guidelines should be followed. They concern the integrity of the surface in 3D printing and the quality of both the CAD based and 3D printed resulting surfaces (Table 1).

Table 1. Guidelines for the 3D printing procedure

| Conditions                   | Description                                                                                                                                 |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Compatible files</b>      | STL are the compatible files that the CAD system exports to be compatible with the 3D printer.                                              |
| <b>Number of polygons</b>    | Using many polygons creates a better surface of the printed object but it can be difficult to manage large pieces of information.           |
| <b>Coordinate system</b>     | It is recommended that the designed object coordinate system assists in improved handling of the geometry within the 3D printing workspace. |
| <b>Non-Manifold</b>          | Continuity of the model volumes is essential (closed geometry model).                                                                       |
| <b>Materials and methods</b> | Depending on the material selection, the rest of the 3D printing manufacturing parameters are set (speed, temperatures, infill etc.).       |
| <b>Scale</b>                 | The scale should be proportional to the requirements of the final model                                                                     |

|                     |                                                                                                                                                                                                                 |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Printer Size</b> | It is necessary to have the size of the 3D printer checked. More specifically, the size of the object to be printed is required to be smaller than the size of the printer. Printing in scale can be an option. |
| <b>Details</b>      | Emphasis should be placed on details. It is good to know that small details (geometrical characteristics) may not be visible when 3D printed.                                                                   |
| <b>Tolerance</b>    | The 3D printed object size can be considerably different from the dimensions set. More research work about the manufacturing parameters selected is usually needed.                                             |
| <b>File name</b>    | Simple name with English characters that is easily recognized should be used, when a lot of files are produced                                                                                                  |
| <b>Orientation</b>  | The object's orientation affects the mechanical properties of the final 3D printed item.                                                                                                                        |

Following the proposed guidelines, the possibility of error during printing was reduced and the process of final prototyping was accelerated. Although there were a variety of 3D technologies available, Fused Filament Fabrication (FFF) was selected in this case study, mainly due to the size of the armchair. The CreatBot™ 3D printer was used (D600 Pro) with useful printing area dimensions of 0.6 m × 0.6m × 0.6 m. PLA EVO was selected in order to increase the printing speed to 50 mm/sec and reduce the printing time to 72 hours (Figure 7).

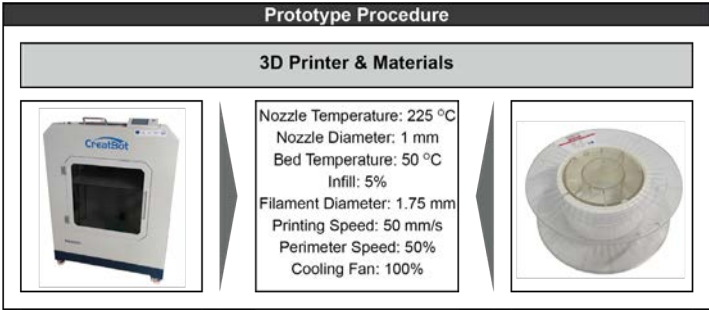


Figure 7. 3D Printer used and its settings

The volume of the final geometry resulted in an approx. 5 kg prototype. No problems occurred during 3D printing, and the surface quality was satisfactory for this application. Then, cardboard was used to create the seat. The

seat was placed inside the printed prototype for completing the product's final layout (Figure 8).

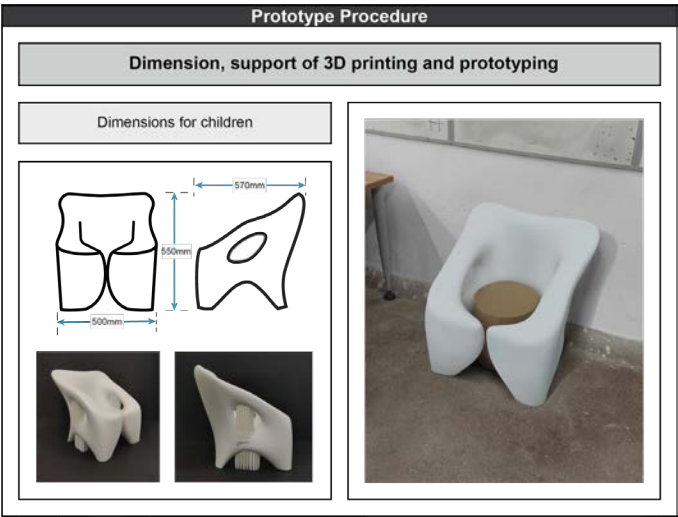


Figure 8. Dimensions, supports and the result of 3D printing

## Results

An early evaluation was conducted based on the opinion of five couples of parents (10 people). Most of them (80%) expressed their approval for building customized armchairs for children with unusual geometries that can attract the user's attention. Although the 3D printing technology at the beginning was considered a positive issue by all the participants, at a later stage, there were concerns about the structural integrity of the products fabricated with this process (60%). All the participants (100%) expressed their satisfaction because their opinion was asked during the armchair unusual geometry design and they felt connected to the design process itself.

## Conclusions

Through this research, a children's detachable ergonomic armchair was developed. The methodological and technological tools used were mind map, 2D digital sketching, 3D CAD modeling (sculpting), rendering and 3D printing. The mind map led to the primary idea regarding the imitation of the tree and its branches. The stool resembled the base of the tree. Then, with the help of the 2D digital sketches, a number of concepts were examined.

The proposed geometry was then digitized in 3D using a CAD system. The 3D CAD models were used for rendering and promotion purposes, taking into account the best practices for color selection, when children are involved as users. Finally, the prototype of the armchair was 3D printed on a 1:1 scale. The prototype was used for an early evaluation procedure and thus involving the customers well ahead in the product design lifecycle. During the 3D printing fabrication process, additional manufacturing guidelines were considered, and the final prototype was prepared with high surface quality delivered.

The prototype was detachable and could also be used as a stool for easier use and transportation. Combining not only an effective geometry of the armchair but also its colorful appearance, a very attractive product for children was developed. The creative approach to the design of the armchair opens new possibilities for its application.

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