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Applying Concepts of Inclusive Design in Sensory Product Design for Children

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Abstract: This paper aims to present the results of an investigation succeeding a Internship of Research Abroad (BEPE/ FAPESP) which sought to expand the theoretical framework on design processes of sensory products in the European Market. The emphasis is on toys for children with blindness or low vision, from its design process all though its physical prototyping. This study structure follows: a) theoretical deepening on children with visual impairment and the design practice of sensory products; b) synchronic analysis of similar products available in the Portuguese Market; c) design conception in the levels of project, generation and selection of alternatives; d) Experimental execution of virtual and physical models in laboratory; e) documentation and analysis of the results. Thus, this research intends to contribute to the development of sensory products for children with visual impairment, and encourage further research in the areas of Product Design and Inclusive Design.

Key words: inclusive design, product design, children with visual impairment, sensory products

1. Introduction and Background

The Research Internships Abroad aimed to explore the theoretical framework on the design process of sensory products. The exchange program focused mainly on toys for children with visual impairment in the European market. It also targets the practice aspects of the design process and completion of a working prototype of a sensory product. This study derives from a Brazilian scientific initiation research in progress called “Prototype development of furniture for children in preschool: Link between Sustainable Design and Inclusive Design”, funded by Sao Paulo Research Foundation (FAPESP). The primary research seeks to address the design of sensory products for five to six year-old children, in order to provide a theoretical and practical deepening in the area of inclusive and sustainable design.

The study abroad was conducted in the Faculty of Architecture, University of Lisbon (FAUL). It sought to acquire a deeper understanding on product design and sensory behavior, attending to the target public of children.

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In addition, the design guidelines proposed by the end of the study included the impacts generated by the product on the sustainable level (Figure 1).

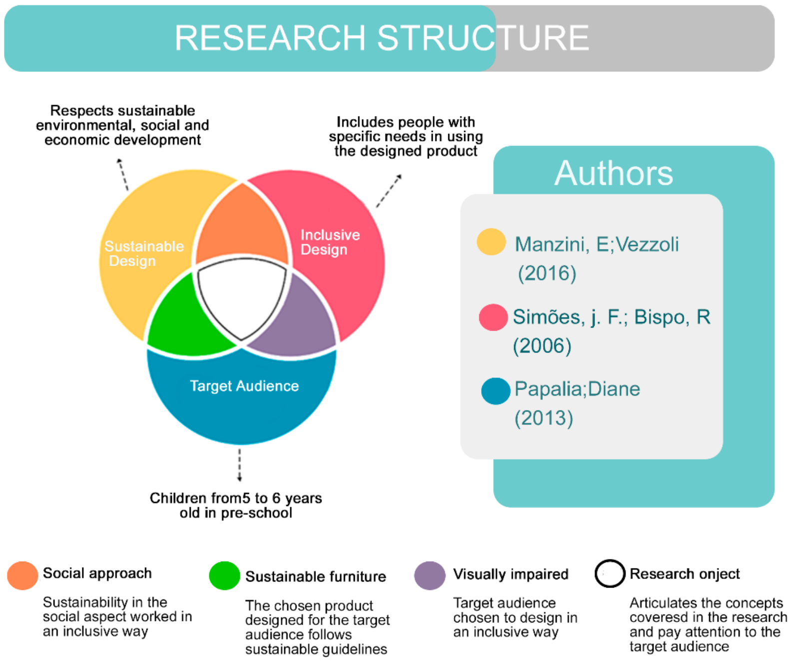

Figure 1 Diagram of the Search Structure

Source: diagram prepared by the author, 2020

2. Theoretical Foundations

Visual impairment can be characterized by significant changes in visual functions such as visual acuity, visual field, sensitivity to contrasts and color vision. From a clinical point of view, as stated by Ladeira and Queiroz (2002), an individual may be considered visually impaired when presenting significant limitations in acuity and visual field. The criteria for benchmarking visual impairment follows the official standards of World Health Organization (ICIDH, DCI -10, 1999), which specify levels into five categories, namely: 1 and 2 (moderate and severe) related to cases of low vision, while the categories 3, 4 and 5 (deep, almost total, and total) refers to cases of blindness. Although deep visual impairment can be noticed mostly during infancy, in cases of low vision it is recurrent a delay in the diagnosis, usually noticeable in learning (Batista, 1998):

> ejection quite usual activities in classrooms for children of their age; lack of some knowledge usually present in children of the same age, such as word exploitation writing, counting, representation of time (day, month, year), game rules and concepts involving pairings (bingo games, domino etc.); unfamiliarity with activities of "pencil and paper" (drawing, writing etc.). It is defined that the activities of "school groups" would favor the objectives of the overall development of children, to increase the likelihood of academic success (Batista, 1998, p. 219).

An early diagnosis is proven to be crucial in studies of evolutionary development of visually impaired people. It shows in different theoretical fields a need for early intervention with the goal of a full development of the child (Piaget, 1975; Fraiberg, 1981; Bruno, 1993; Leonhardt 1992; Buutjeans, 2002; Brodin Rivera, 1999a). Thus, as proposed by Rosel (1980), children with severe visual impairment may have in the course of their development, subtle delays in obtaining fundamental behaviors. That can trouble processes such as gait learning and basic skills of personal autonomy, in acquiring social habits and some cognitive notions (Siaulys, 2006), “which should be taken as a natural development of the blind child and cannot be diagnosed as pathological” (Rosel 1980 cited by Guinot, 1989, p. 30).

The vast majority of studies on the cognitive development of congenital blind people are held in Piaget's perspective. Among them, Hatwell (1986) Ochaíta (1984) and Guinot (1989) point out that children with visual impairment may be held back two to three years from the acquisition of symbolic function, and up to four years in handling of figurative and spatial elements. This delay can be alleviated from the moment that verbal language assumes the function of representation and organization of knowledge (Siaulys, 2006). Peraita, Elosua and Linares (1992) emphasize that spoken language for the blind children becomes a primary mean to obtain knowledge from the physical and social environment, thereby offsetting the visual information (Siaulys, 2006).

In addition to cognitive aspects, Mendonça et al. (2002) warn us about impacts on the development of psychosocial skills of the visually impaired children. He points out that without the possibility of mimicry of their peers and use of nonverbal communication, those kids struggle with social skills development, which in turn makes it complicated for them to be accepted by their peers. This is due, according to Vygotsky (2003), to the fact that the social experience is largely achieved by a mirroring process. As exemplified by the author, the child mimics the way in which the adult uses instruments and manipulates objects, trying to master the true principle involved in a particular activity (Siaulys, 2006).

Thus, sight plays an important role in the development of an individual as a whole, and without it, it is necessary to establish alternatives to the enrichment of information taken in from the external environment. In short, there is enough evidence supporting a tendency to for visual impaired children to repeat concepts using words with insufficient knowledge of its meaning, and set in a fragmented manner the understanding of its actual content. That is due to the lack of attention to the enhancement of sensory input transmitted to the kid, combined with poor translation of visual stimuli to verbal or tactile information, combined with unsatisfactory diversity in sources of information so that the brain can form a whole concept of its surroundings (Piaget, 1975; Fraiberg, 1981; Bruno, 1993; Leonhardt, 1992; Mansini, 1994; Buutjeans, 2002; Brodin & Rivera, 1999; Siaulys, 2006; Vygotsky, 1983; Martin & Bueno, 1997; Mendonca, Miguel & Cols, 2002; Papalia, 2013; Montessori, 1995).

To assist a more effective development, Vygotsky (year) suggests that the assimilation of concrete sensory knowledge is necessary to help the acquisition of concepts without untying the sensitive rational. Thus, in terms of early development, from five to six years of age, “playing” has a significant role in improving the overall development on an infant (Papalia, 2013). Just like in sighted children, for those with visual impairment, playing can encourage the assimilation of concepts, improve psychomotor skills, cognitive achievements, and especially, intermediate concrete sensory knowledge acquisition that is vital for rational conceptions.

It is precisely in this way that the Inclusive Design works, when designing for diversity, with an early integration in design processes of technical aesthetic and psychological concerns that interfere with the use and perception of the object (Simões & Bispo, 2006). In this sense, designing sensory product for visually impaired children must follow the principles of Inclusive Design, considering that:

> The Inclusive Design is also reflected in the design practice, a democratic practice, respect for human rights, and defense of equal opportunities conditions. Most barriers to the involvement of many citizens in democratic life, that limit the full exercise of active citizenship, are designed and built by men. It is therefore necessary to be always present a new attitude to the social dimension of design practice. It is necessary that the

designer strives to understand the fitness for use of spaces or products is to design (Simões & Bispo, 2006, p. 8).

3. Application of a Synchronic Analysis

The synchronic analysis was made through data collection of sensory products available and registered in Lisbon, with an emphasis on those targeting the sensory stimulation of children with visual impairment. The products were then analyzed for its conditioning parameters. Therefore, field trips were made to traditional toy stores, as well as sustainable and educational oriented toy stores. Complementary, a virtual search of these types of toys/products was also carried out. It is worth underlining the importance of visiting physical stores at this stage of the research, because when designing for children with visual impairment, the multisensory aspect is crucial. In this sense, those visits provided physical experimentation with the textures, materials, shapes and sounds of each object.

Among the different types of products and after the choice of basic criteria of inclusion and compliance with the target audience, there were chosen two product lines: a) toys with sensory stimuli; b) set of tools with engine processing.

Data collection procedures were organized according to the following parameters: i) the characterization of the material used; II) photographic record; and III) provided sensory analysis processing (Table 1).

Table 1 Analysis of Similar Products

Product	Analysis
Tool kit plastic 	**Material**: Plastic derived from petroleum, has a homogeneous smooth texture. **Processing:** Found in several stores and manufacturers, this set provides great motor improvement and has vibrant colors, however, the choice of color contrast is unfavorable to several visual needs, such as color blindness.
Shapes and Colors - Goki 	**Material**: Made of wood, with homogeneous texture. **Processing:** Product from the shop "Happy Grove". It features large motor improvement, with self-corrective activity and an emphasis on fine motor development. It has pleasant and contrasting tones of color, but its diversity of hue reduces the efficiency in some cases of deficiency.
Lustigt 	**Material**: Made of wood and fabric cord. **Processing:** Product from the store "Ikea". It has great fine motor skills improvement, and stimulates important mathematical associations. This is a toy with little contrast and textures.

Bag Touch Memory - Goki 	**Material**: Made of wood combined with several textures and materials on its top surface. **Processing:** Product from the shop "Happy Grove". It shows great motor and sensory improvement, mainly because of the wide range of textures and bold colors working independently, which enables the cognitive development of memory, a crucial skill for the target audience.
Sensory blocks 	**Material**: Made of wood, with a variety in textures and surface finishing. **Processing:** Product from the shop "Happy Grove". It sets to prompt fine motor skills and large sensory stimulation through colors, textures and sounds. Suitable for the target audience.
Tool box - EverEarth 	**Material**: Made entirely of wood, with natural and painted surfaces. **Processing:** Product from the shop "Happy Grove". It sets to encourage major improvement on fine motor skills, with great stimulation of imagination, creativity and motor coordination. It features bright colors, which might hinder the viewing of children with some types of visual impairment.
Tool box /Desktop-Goki 	**Material**: Made of wood, with homogeneous texture and detail in painting. **Processing:** Product from the shop "Happy Grove". It shows great improvement engine, similar to the previous product this one allows for great stimulation, but seems difficult to use for the visually impaired due to the choice of colors and the use of natural color.

Photos Extracted from shopping sites; text written by the author, 03/24/2020

4. Design Development with Proposition and Selection of Alternatives

This step of the research comprehends the process of generating alternatives, selecting promising ideas, working on improvement and feasibility in terms of shape definition, color, texture and finish with hand sketches, virtual models and renderings.

4.1 Proposition of Alternatives

The stage of proposing ideas was conducted by understanding and concatenating the bibliographic data and synchronous analysis presented in the Table 1, using sketches and annotations of possible variations in design of products and paths to folow into the conception process. Four alternatives were created at total, allowing the analysis of features such as feasibility and compliance with the design requirements of the targeted public.

4.2 Selection of Alternatives

Among the four ideas proposed in the last stage we selected two to move onto the prototyping phase: 1) Sensory Case; 2) Wood Toolkit.

1) The first idea is a multi-sensory game, set to work on tactal, hearing and sight skills simultaneously (Figure 2). The Sensory Case focuses on the act of playing, and would guide the exploration of sensory experiences in a self-correcting manner. Thus, by their own attempts and fails, the child would trigger their "System of action", which is a mechanism of combining different skills in favor of the motor skill development. It stablishes a parallel between the kid's operational logic and that of the toy functioning while being played with. That whole process would allow the child to learn by creating a motor repertoire that can continuously merge the skills that the child already possesses with those he/she could acquire. It means that the Sensory Case could stimulate the acquisition of more complex capabilities.

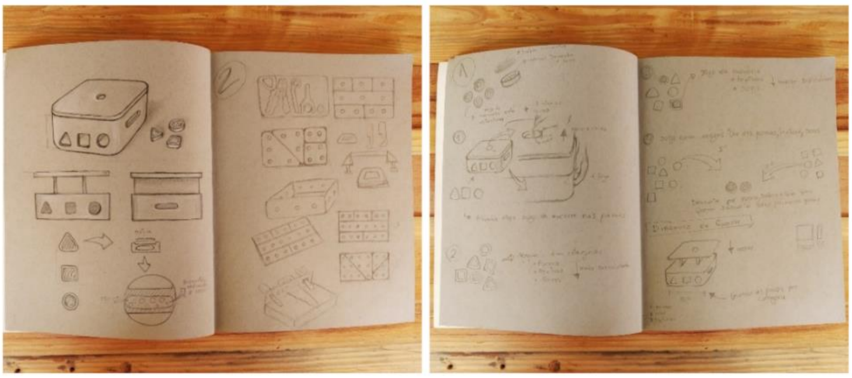

Figure 2 Sketches Made by Hand, by the Author (03/23/2020)

The Sensory Case was designed to be used in conjunction with the Sensory Table. The measures and form of that object stimulate a sequence of actions set out in the act of "Catching" the toy. Thus, the first portion of the action starts by seeing and feeling the housing cover and the central opening of the lit which, when raised, separates itself from the rest of the box. Then the main playing and experiencing of the object starts, when the lit releases the parts within the box so that the kid can move and mix them.

In total, the box has 18 pieces inside of it, varying in shape, texture, color, material and sound. When removing the pieces, the child that is playing begins a process of investigation of the contents. That firstly allows for the task of grouping the items by similar characteristics such as shape, texture and sound, each feature with its own levels of difficulty. After the assimilation of those features, it is expected that the pieces can be used for simple games of configuration such as the memory game.

As much as the attempts and fails of the grouping phase, the step of the memory game can be performed following the shapes, textures and sound, with a growth of difficulty and learning in the process. With gestures of "catching", "playing" and "signifying" the object can be explored in a multi-sensory way, thus embarking a wide variety of specific needs, including the visual ones. It was also studied the dynamic involved in storing the parts of the toy, since the shape of the box only allows that all parts are stored if the product cover is closed, and then each piece must be placed individually in the respective front opening. This process may be understood after repeated trials and errors, and it adds benefitial steps to be stimulated, as coordination, reasoning, sensory exploration, and autonomy.

2) A set of woodworking tools, named Wood Toolkit, was the second selected idea. It seeks motor skills improvement by promoting various gestures of use and also delicate and fine movements. This toy introduces mathematical proportions such as ½, 1/3 and also elemental geometric shapes such as rectangles, circles, triangles and simple polygons in the design of its parts. It encourages wishful thinking while simulating activities of possible professions, it also fosters creative development because it is composed of moving parts that can be arranged and rearanged in various ways. The pieces that imitate tools have the same functional character of their original counterparts. Thus, the playing tools can be handled to build many objects that can later on be used and reinvented by the child (Figure 3).

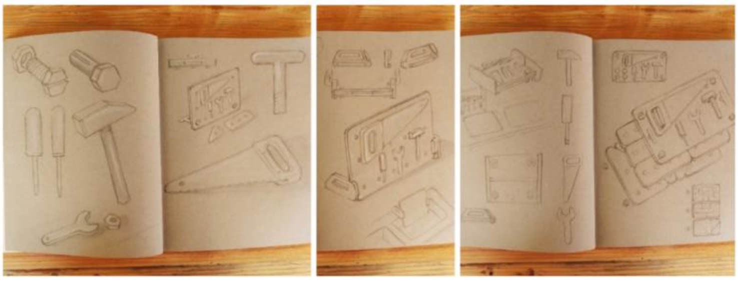

Figure 3 Sketches Made by Hand, by the Author (03/23/2020)

In order to optimize the Wood Toolkit for the targeted public, the parts were designed with high contrast (aiming at children with low vision) along with a possibility of strengthening relationships done by linking the possible used tool through color, shape and texture.

4.3 Color Choice

In terms of visual impairment, severe blindness is relatively small in percentage, which means that the enhancement of residual vision is critical to achieve a wider diversity. Thus, the contrast of color can work as a strategy to augment the use. Being so, the colors were carefully chosen, several combinations were tried with markers in paper sketches along with a simulated contrast test through virtual modeling software. It is worth pointing out that extensive attention was given to the process of chosing the toolkit colors, because it possesses a large number of pieces and various possible setup configurations. So it was fundamental caring for the right amount of contrast in the color of its pieces (Figure 4).

Figure 4 Color Tests With Markers on Paper, by the Author (03.23.2020)

4.4 Virtual Modelling and Renderings

In this next stage of the conception a series of virtual 3D modellings of the two proposals were made. That was only feasible because the previous settings had already been decided. The virtual models made possible verifying the constructive viability and the aesthetics of the products (Figure 5).

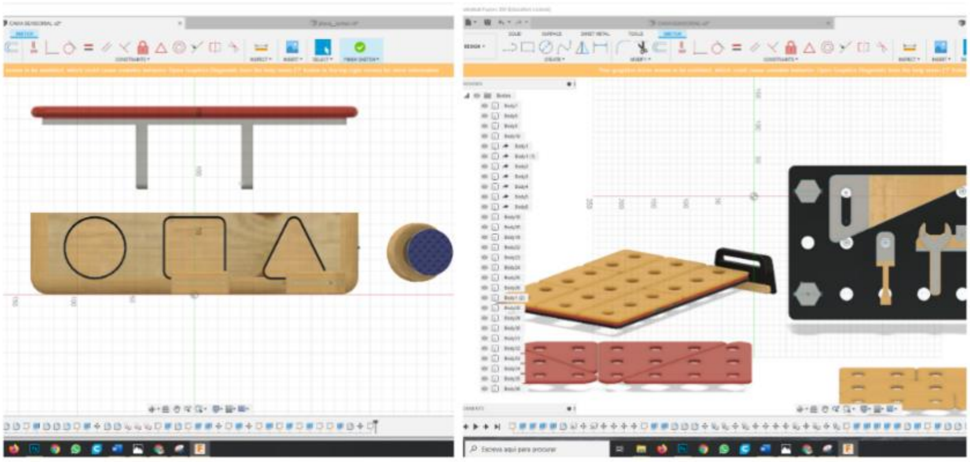

Figure 5 Virtual Models Design With Autodesk Fusion Software, By the Author (03.23.2020)

After modelling it virtually, both solutions were rendered (Figures 6 and 7).

Figure 6 Digital Renderings of the Sensory Case, by the Author (03.23.2020)

Figure 7 Digital Renderings of the Wood Toolkit, by the Author (03/23/2020)

4.5 Experimental Execution of Physical Models in Laboratory

At this stage, a physical modelling study was initiated with the proportions and materials. In order to define the right measures and scale of the physical models, it was necessary to simulate the actual size of the sensory table with which the two designed objects would interact.

When the activities with the fictitious Sensory Table started, it was noticeable that the ideal modelling scale should be 1:1. Considering the need for use of the same materials intended for the final product, it was decided to develop a working prototype, instead of a model. In sequence, we used the infrastructure of FAUL, its workshops, for the manufacturing of the two proposed solutions (Figure 8).

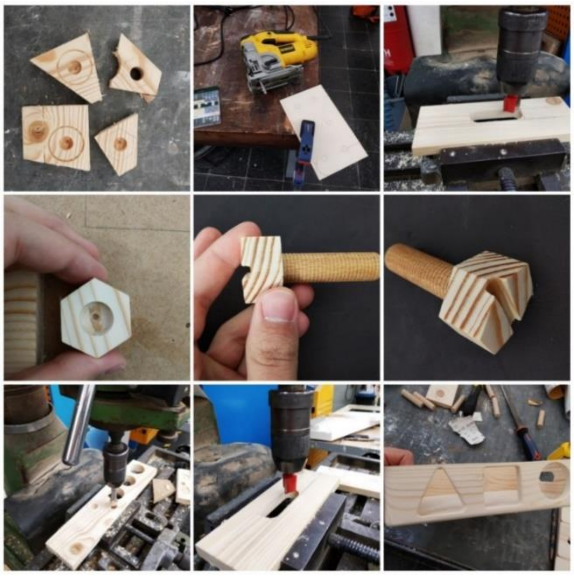

Figure 8 Photos Presenting the Prototypes of Both Products in Production, by the Author (03.23.2020)

The following image shows several moments in the manufacturing process of both proposed solutions (Figure 9).

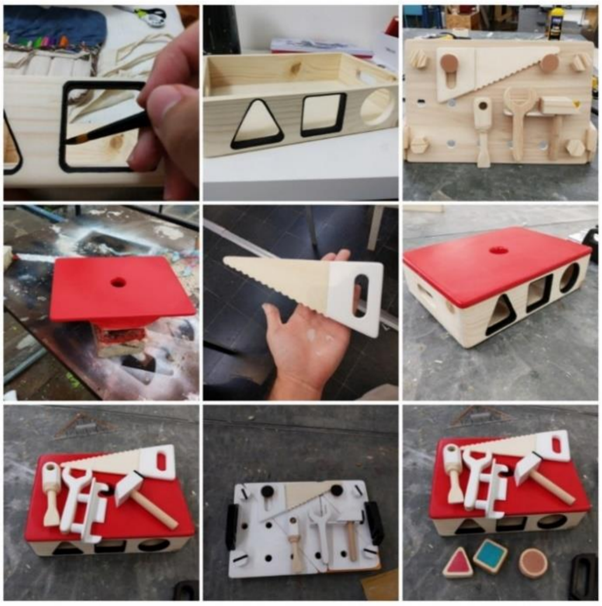

Figure 9 The Finishing Process of Both Prototypes, by the Author (03.23.2020)

Furthermore, the Figure 10 presents the prototypes of the proposed Sensory Box, finished and functional. Black and red colors compose its outer interface. Details in black covering the side apertures were set to optimize contrast with the lightwood. That feature can be helpful mainly for cases of residual vision in which positioning the pieces into the box might be harder. The hollow side handles become visible when the toy is removed from its place in the Sensory Table. The aperture of the handles were designed to be smaller than the geometric shaped pieces, but big enough to provide a secure grip for the child when he/she wants to lift the box.

Figure 10 Photo of the Sensory Box Prototype, Developed by the Author (03/23/2020)

The parts that make up the box are hollow inside and filled with different materials to provide three different types of sounds (Figure 10). Three pieces were produced, out of eighteen possibilities in the total game, representing the three possible types of elementary forms, textures, colors and sounds in the game.

The Wood Toolkit allows for several association reinforcement tasks. One example is that the tools and its combining parts match in terms of color, shape and texture thus facilitating the assembly, disassembly and the overall engagement of children with visual impairment (Figure 11).

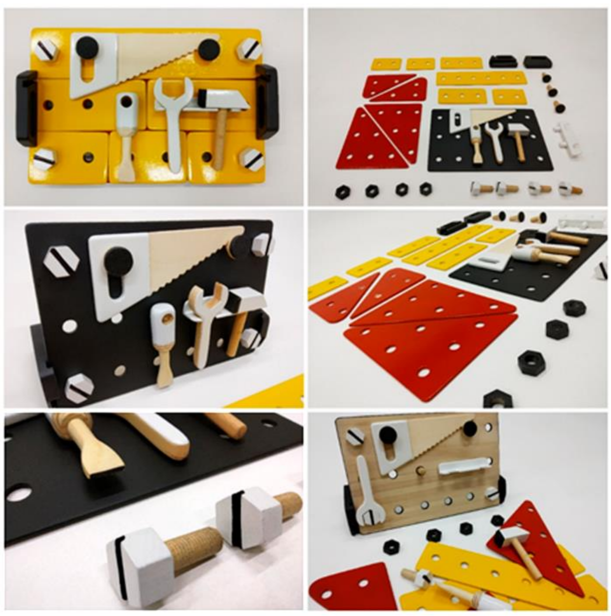

Figure 11 Photo of the Wood Toolkit prototype finished. Developed by the author (3/23/20)

5. Conclusion

Finally, by analyzing the results, it can be concluded that the goals of the study have been met and, moreover, it was possible to carry out the production of two prototypes with complex operations in a short period of time. That is, the initial plans of producing only scale models were exceeded. Generally, it is expected that these results may contribute with the theoretical and practical knowledge in the field of design as much as in methodology of design projects that could be applied in similar studies. That being said, this study still needs to carry out tests of the prototypes produced, with visually impaired children. After that, inclusive factors may be assessed in order to confirm if they meet the audience's needs. That will allow us to iterate in the process of making changes and improvements towards a subsequent validation of the proposed solutions.

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