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DESIGN ORIENTED TO ASSISTIVE TECHNOLOGY BASED ON THE INTEGRATED DEVELOPMENT PROCESS OF A SUISTAINABLE PRODUCT

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Abstract. *This research is focused on issues of environmental sustainability and social inclusion in the Integrated Product Development Process (IPDP) to elaborate a component of a solar water heating system using discarded and recyclable materials in a way that people with visual impaired can be involved with its manufacture. For this, it was developed tools that offer safety and comfort to the user in the construction of the prototype component. The construction of the component prototype and the tools happened during the IPDP phases based on the principles and concepts of product ergonomic, usability and renewable energy. Firstly, the discarded and recyclable materials were separated, analyzed and prepared according to their use in the component. The research explored the Universal Design and Accessibility themes to understand the requirements of the users with disability making possible the development of the tools to support all the people involved in the component construction and serving as an Assistive Technology instrument which allows the activities execution by people with disability. The study presents, too, the IPDP attributions to elaborate products to the Assistive Technology, which aims the participation of people with disabilities in the process so it contributes to social inclusion.*

Keywords: Assistive technology, Solar water heating system, Discarded and recyclable materials, Social inclusion, Sustainability.

1. INTRODUCTION

In the current competitive scenario it is important to develop products with quality, lower cost and in an innovative way. Thus, the area of Product Development is addressing the tools and methodologies to design new products taking into account the technical and functional aspects. In addition, others quite important issues are environmental sustainability and social inclusion. The environmental sustainability began to be diffused when the Brundtan Report appeared in 1987 and until today the world authorities have been strongly directed towards the goals outlined in the Millennium Development Goals. In the huge area of the Millennium Development Goals accessibility is a key theme for the achievement of sustainable and equitable development allowing the creation of favorable environments for the full participation of persons with disabilities on an equal basis with others in all aspects of life in society and development (UN, 2012). With that, the path for Assistive Technology is opened, the National Secretariat for the Rehabilitation and Integration of People with Disabilities (SNRIPD) of Portugal defines as "products, tools, strategy, services and practices used by people with disabilities and elderly people, especially produced or generally available to prevent, compensate, relieve or neutralize an impairment, disability or handicap and improve the autonomy and quality of life of individuals "(PORTUGAL, 2007). This aspect involves the attributes for the social inclusion of people with a special need as nowadays about 15 percent of the world's population, or 650 million people show a deficiency (UN, 2012) and as the 2010 preliminary Census presented by IBGE (2011), 23.9% of the population has at least one of the investigated disabilities.

In this context, this research analyzed the themes of environmental sustainability and social inclusion in the Integrated Product Development Process (IPDP) with the objective of creating a component prototype of the Solar Water Heating System (SWHS) using recyclable materials from domestic disposal with the participation of visually impaired people in its manufacturing process.

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1.1 Methodology

This research is considered applied nature and it has a qualitative approach, its scientific objective is exploratory and the technical procedures are the literature review and case study. In this study was elaborated the manufacturing process for the manufacture of the solar collector of the SWHS based on the framework proposed by Okumura (2012), showed in Figure 1. This framework uses Simultaneous Engineering as support to the development of inclusive products, that is, products that meet the highest number of users with and without disabilities.

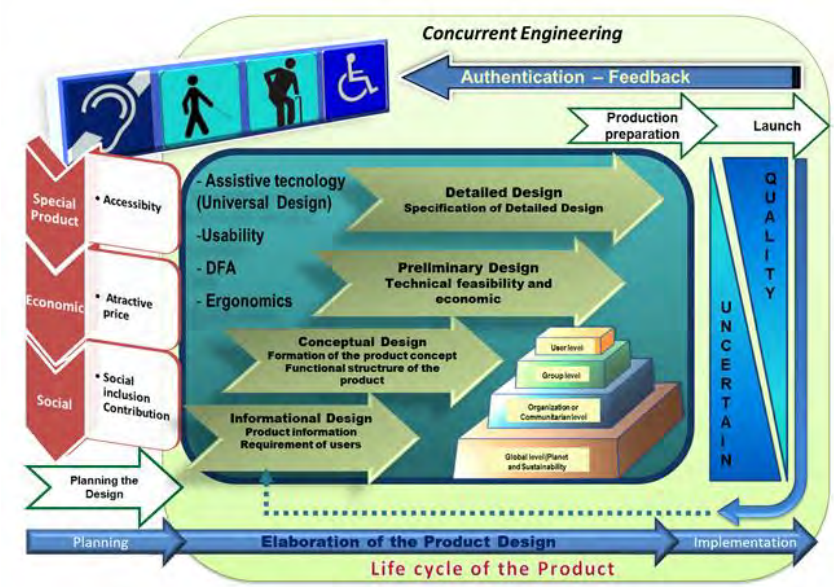

Figure 1 – Framework proposed by Okumura (2012)

2. LITERATURE REVIEW

2.1 Assistive Technology

The Committee on Technical Assistance (CAT) and the National Co-ordination for the Integration of Persons with Disabilities / Special Secretariat for Human Rights (CORDE; SEDH, 2007) defined the assistive technology is: "an area of knowledge with interdisciplinary character, that includes products, resources, methodologies, strategies, practices and services that aims to promote the functionality related to the activity and participation of the persons with disabilities, incapacity or reduced mobility, seeking their autonomy, independence, quality of life and social inclusion".

2.2 Integrated product development Process

The Integrated Product Development Process (IPDP) is inserted in companies and in the market and is up to it to identify the market needs and propose solutions. Its importance is to identify the desire of the consumers, the market needs and the technological discoveries generating a product according to the requirements: quality, time, cost and manufacturability (Back *et al*., 2008). According to Rozenfeld (2006) the product development is a business process increasingly critical due to the internationalization of the markets, the increasing diversity of products and the reduction of its life cycle. Thus, new products seek to meet specific market segments, incorporating the latest technologies and adapting to the standards and legal restrictions. To the same author, the IPDP activities are classified mainly into three stages which comprise pre-development, development and post-development.

2.3 Sustainability

The term "sustainable" was diffused by Brundtlan Report in 1987. Since then, the issue of sustainability has been discussed, and its definition is " the development that meets the needs of the present without compromising the future generations ability of meeting their own needs" (Brundtland, 1991), that is, the need of an intelligent development without harming the environment in order that in the future, natural resources can continue to exist.

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2.4 Accessibility

The Accessibility is to allow the participation of people with disabilities or reduced mobility in activities that include the use of products, services and information aiming their adaptation and locomotion eliminating barriers. The Decree No. 5.296/2004 considers accessibility: "the condition for use, full or assisted, with security and autonomy, of the spaces, furniture and urban equipment, the buildings, transport services and devices, systems and communication and information means by the person with a disability or reduced mobility".

2.5 Universal Design

The Decree No. 5296 of 2004 introduces the concept of "Universal Design" as: "the conception of spaces, artifacts and products that aim to meet simultaneously all people with different anthropometric and sensory characteristics, in an autonomously, safe and comfortable way, constituting in the the elements or solutions that compound accessibility"(Lima, 2007). Thus, the universal design consists in meeting the widest possible range of anthropometric and sensory characteristics of the population integrated into the context of accessibility and comprises seven principles to be applied as a tool in the design of products and environments, which are listed below (Story *et al*., 1998):

a) Principle 1: Equitable Use – The design is useful and marketable to people with diverse abilities;

b) Principle 2: Flexible Use – The design accommodates a wide range of individual preferences and abilities;

c) Principle 3: Simple and Intuitive Use – The design is easy to understand, regardless of the user´s experience, knowledge, language skills, or current con-centration level;

d) Principle Four: Perceptible Information – The design communicates all necessary information effectively to the user, regardless of environment conditions or the user´s sensory abilities;

e) Principle Five: Tolerance for Error – The design minimizes hazards and the ad-verse consequences of accidental or unintended actions;

f) Principle Six: Low Physical Effort – The design can be used efficiently and comfortably with a minimum of fatigue;

g) Principle Seven: Size and Space for Approach and Use – Appropriate size and space are provided for approach, reach, manipulation, and use regardless of user´s body size, posture or mobility.

2.6 Ergonomics

According to Iida (2005) Ergonomics is the study of the adaptation of the work to the man, adjusting to the human capabilities and limitations. The Ergonomics Research Society (1950) defined the concept of ergonomics as: "the study of the relationship between man and his work, equipment and environment, and particularly the application of knowledge of anatomy, physiology and psychology in solving problems appeared in this relationship". It has as practical objectives the safety, satisfaction and well-being of workers in their relationship with the processes.

One principle of ergonomics is to optimize the individual's relationship with the environment in which it is inserted and with the tools he uses to perform its activities. The Ergonomics has great importance for ensuring the safety, health and well-being of the individual assisting people in their work contexts to work safely and preferably pleasurable. With a diagnosis is possible to design artifacts (objects, tools, equipment, work environment, work organization etc...) that people interact and thereby adapt these artifacts to the capabilities and limitations of a person or a group of people who work in a cooperative manner. From the moment when the conditions are designed taking into consideration the human characteristics, the work becomes less painful and more compensating for whom executes it (Zamberlan, 2013).

2.7 Usability

Usability means easiness and convenience use of the products in the home or business environment. According to ISO 9241-11/2002 - Ergonomic office software defining by the International Organization for Standardization- usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specific use context.

2.8 Renewable Energy

Brazil has been a world example in the use of renewable energy as it maintains, since the 1970s until 2009, energy sources ranging between 61% and 41% originated from renewable sources (IPEA, 2010). Despite all the positive aspects of solar energy it is rarely used because the financial costs for obtaining energy are very high and it is not economically viable (ANEEL, 2002).

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3. DEVELOPMENT

The manufacturing process of the component of the solar water heating system (SWHS) was based on the framework proposed by Okumura (2012) following the design phases of the development of inclusive product (informational design, conceptual design, preliminary design and detailed design).

Firstly, the discarded and recyclable materials were separated, analyzed and prepared for use. Later during the IPDP phases, it was created tools using the concepts of ergonomics and usability. Meeting the terms of the instrument of Assistive Technology that enables the execution of activity for people with disabilities, the research focused on the principles of universal design and accessibility comprehending, in this way, the user's with visual disabilities requirements.

According to Rozenfeld *et al*. (2006), the informational design defines the product requirements from customer demands. Thus, the information was collected through observation of the activities and support materials used by persons with disabilities. After analyzing this information, it was realized how important is the touch perception for people with visual impairment, making relevant the product characteristics as the form, texture, noise and the senses necessary for the materials perception of. In this term, it was observed the options of disposables and recyclables materials selecting the most suitable to meet both the requirements of manufacturing and the participation of people with visual impairment. The materials selected was the ones that offer greater tactile perception to facilitate handling and assembly of the SWHS component, for example, for the PET bottles, the selection criterion was the most used and discarded, as well as the embossed marking coinciding with the place where it should be cut.

Baxter (2000) notes that conceptual design should show how the new product will be made to achieve the basic benefits. Thus, the recyclable materials and support tools need to be easily recognized by the visually impaired person to handle, recognize the object by texture and by the hearing when it is moved, hold or tighten. Rozenfeld *et al.* (2006) argues that the conceptual design shows how the generation and selection of product conception occurs from the specifications that are the goal of the resulting product of the informational design phase. Thus, it was observed that the PET bottle, Tetra Pak packaging, PVC pipes, scissors, stiletto, sandpaper and other tools have texture and shape for object identification. In this research was also observed the need to clean, wash and dry all the recycled materials for conservation and also for hygiene preserving people's health.

For people with visual impairments the cutting of PET bottles is done using a template, made from pvc pipe, as proposed by Alano (2004) and shown in Figure 2 providing safety and cutting precision.

Figure 2 – PET bottle cutting proposed by Alano (2004)

In the preliminary phase of the design it was analyzed the preparation of the SWHS components from discarded and recyclable materials. The Tetra Pak packaging after being washed and cut were painted in black and folded as described by Alan (2004), having the function of heat absorption. The process of folding the box can be performed by visually impaired person since it uses a pre-cut template. For the PVC pipe cutting it was fabricated a template to obtain pieces of uniform size and so it can be safely used by people with visual disabilities.

In the detailed design, according Rozenfeld *et al*. (2006), it is planned the manufacturing process of the components and assembly of the subsystems, systems and the final product within the concept of concurrent engineering, also considering the manufacturing design resources and factory design. In this aspect, the process for this study was the manufacture of prototype of the SWHS solar collector, as illustrated in Figure 3, following the instructions in the manual of Alano (2004). It was performed the following activities: washing of the recyclables materials (detail A); PET bottles cutting (Detail B); Tetra Pack packaging cutting, painting and folding (Detail C); PVC pipes cutting and painting (details D and E); Tetra Pack packaging setting within the PET bottles (Detail G); placement of the pipes within the PET bottles (Detail G) and connection of the parts through PVC pipes (detail F).

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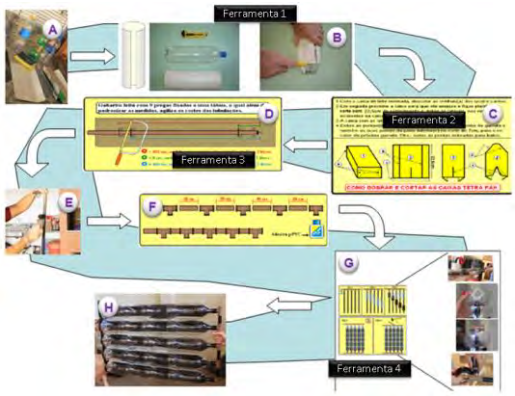

Figure 3 – Manufacturing process based on Alano (2004)

For the cutting the PET bottle step (detail b) was developed the tool number 1,which is a template made of PVC pipe, that fits in the bottle marking exactly where the cutting should be done, as shown in Figure 4.

Figure 4 – First template for PET bottle cutting (Author, 2013).

However, it was observed that the template suggest by Alano(2004) was not safe for use by visually impaired people, because it could slip over the bottle, so that it was developed another model (Figure 5) which locks the mold and allows the cutting to be made more safely and accurately.

Figure 5 – Definitive template for PET bottle cutting (Author, 2013).

For the Tetra Pak packing (detail C) was created a template, the tool number 2, for folding it, as shown in Figure 6. Firstly, the packing are cut according to the already existing bends, then the template is placed on the top and the route of folding is followed.

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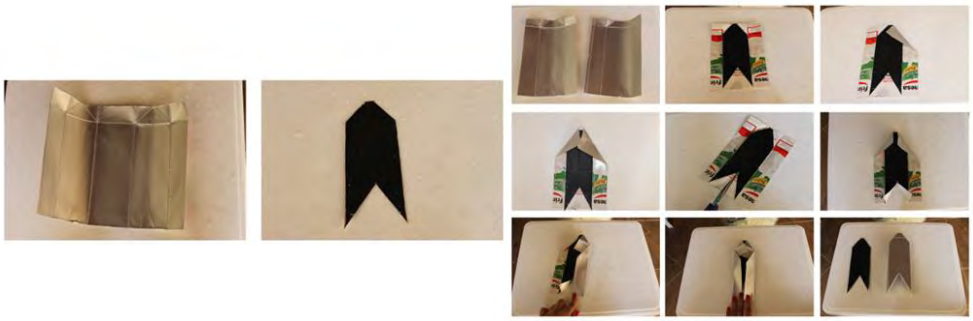

Figure 6 – Template for Tetra Pak packing folding (Author, 2013).

For the PVC pipe cutting (detail D and F) it was required the creation of a tool, tool number 3, for fitting the pipes and obtain the exact position and size required for cutting, according to Figure 7. This template has the required cutting measurements.

Figure 7 – Tools for PVC pipes cuttings (Author, 2013).

Now, for the column assemblies (Figure 8) was made a tool, tool number 4 to fit the PVC pipe, forcing it to stay in place, allowing the assembly of the Tetra Pak packing in the PET bottles. The figure 9 shows the tool number 4, used for fitting the connection in order to keep the structure in position. Using the same tooling for cut the pipes on the other side.

Figure 8 – Tetra Pak packing assembly in the PET bottles (Author, 2013).

Figure 9 – PVC pipe fitting (Author, 2013).

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4. ANALYSIS OF THE RESULTS

The SWHS comprises three components: solar collector, the water storage structure and water transport structure. This research focused on the manufacture of a component of the SWHS, the solar collector, shown in Figure 10.

Figure 10 – Solar collector (Author, 2013).

By the studies of literature and through analysis of the people with visual impairments daily routine, it was possible to elaborate and fabricate a SWHS solar collector (Figure 10) that allows the participation of people with visual disability and in order to achieve this some tools were developed to facilitate the manufacturing processes for all users.

Thus, the research results follow the seven principles of universal design and can be applied in solar collector along with the concepts of ergonomics, usability and accessibility. Therefore, the SWHS manufacturing process relates to the universal design principles below:

a) According to the egalitarian principle it is important to show the importance of the organization and logical distribution of materials and tools in the manufacturing environment to facilitate and optimize the process making the environment the same for everyone;
b) Concerning to the principle of flexibility is possible to relate it to the usability in the manufacturing of this product which is used by specific users, visually impaired people, to achieve the specific goal of social inclusion with effectiveness, efficiency and satisfaction using the product design to attend people with visual impairment and being adaptable for any use;
c) The principle of simple and intuitive use worked together with the ergonomics adjusting the manufacturing process to the worker, people with visual impairments, making its construction easy and for this it was necessary to create a specific tooling;
d) According to the Perceptible Information principle, which is the necessary information transmitted in order to meet the needs of the receiver, it was developed a tooling of ease perception that allows people with visual disabilities participate in the manufacture of solar collector taking into account the product requirements related to the form, texture, noise, and necessary senses for this easy material perception;
e) With the principle of safety, the application of the methods of the product ergonomics, which aims to practical safety, satisfaction and well-being of workers in their relationship with the processes which has as a practical objectives the worker's safety, satisfaction and well-being in his relationship with the processes enabled to create the tooling in a manner to minimize the risks and possible consequences of accidental or unintended actions, for example, the PVC pipe template used for cutting PET bottles provided a safer procedure;
f) The principle low physical effort is in the process of not presenting difficulty and effort from the user to locate the PVC column position, which facilitates the assembly of the Tetra Pak packing within the PET bottles and in the PVC pipe;
g) Regarding the issue of accessibility, this paper presented tools PDIP setting dimensions and spaces suitable for access, reach, manipulation and use, regardless of the physical size of the person, as well as posture or mobility of the user during the manufacturing process.

Thus, if the tooling is designed together with the assistive technology, it provides an accessible manufacturing process, that extends to the IPDP promoting for everyone's participation.

5. CONCLUSION

This research addressed the concepts and tools of the IPDP and Assistive Technology, according to the framework proposed by Okumura (2012) in Figure 1, to elaborate the manufacturing process of the solar collector panel within the context of environmental sustainability and social inclusion. Thus, it was necessary to develop a tooling using the concepts of ergonomics, usability, and accessibility to encompass the principles of Universal Design and Assistive Technology in order that people with visual disabilities can participate in the construction of one of the component of the SWHS. During the process it was verified that there is a lack of accessible tools for full participation of people with

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visual impairment for the manufacture of solar collector, such as the painting of the Tetra Pak packing and PVC pipes, whose activities are suggestions for future research.

Therefore, the research showed that if in all phases of the IPDP it is involved, mainly in the manufacturing process, the aspects of the environment and considered the sensory limitations of visually impaired users, taking into account the process in an integrated and simultaneously, it allows the development of sustainable product that promote environmental sustainability by reusing discarded and recyclable materials and social inclusion by enabling accessibility in the process of product development.

6. ACKNOWLEDGEMENTS

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8. RESPONSIBILITY NOTICE

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