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Article

Sustainability in Design Education: Introduction of Life Cycle Assessment (LCA)

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Abstract: The activity of industrial design is adding tools focused on sustainability to contribute to traditional design methodology. One such tool is the Life Cycle Assessment (LCA) which are several software alternatives and different methods of analysis. The Life Cycle Assessment plays a very important role to understand the best alternatives of selecting of materials and processes in a product. Confronting with consumer activity, with an estimated useful life of the product increasingly short, reflect on the selection of materials and processes appropriate to each project through the LCA provides a powerful tool to support the project, making it essential when talking about sustainability. In this manuscript intend to reflect on the material selection in product life cycle, exploring an analysis tool life cycle in two types of products with low technological complexity, "squeeze bottle" and "lamp". Through exercises in disciplines of sustainability in design courses show up different analyzes for the same type of product, reflecting on the choice of materials and processes these. It was used for the analysis of Life Cycle Assessment the software CES EduPack with Eco Audit Tool. Students become stimulated to study more stiffness the correct selection of materials in the design phase, covering all stages of the life cycle of these products, which allowed students to visualize more clearly the necessity to have a systemic view of the entire life cycle of this product. The results show the complexity and importance of proper selection of materials and processes for sustainability.

Keywords: Sustainability; Life Cycle Assessment; Sustainable consumption; Education.

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1. Introduction

With increasing innovation have today become increasingly, the production of products which end up generating waste and greatly increasing the volume of garbage dumps and landfills. Added to this the fact that the goods are, increasingly, with a reduced service life. Thus, many researchers [1-9] study alternatives to the disposal of products that do not harm the environment.

The activity of industrial design is adding tools focused on sustainability to contribute to traditional design methodology. One such tool is the analysis of Life Cycle Assessment (LCA) which has several software alternatives and different methods of analysis. The Life Cycle Assessment plays a very important role to understand the best alternatives of materials and processes in selecting a product.

In this paper the purpose is to reflect about material selection in Life Cycle Assessment, presenting LCA studies developed in the discipline of design and sustainability at the University UNISINOS, in bachelor degree in Design and technologist in Product Design. These studies were designed to examine one type of product, *squeeze*, performing a comparative analysis of six models of this product. Explores thus the tool Life Cycle Assessment, reflecting about the selecting materials and processes

Aim to link theory and practice, promoting the integration of students with concepts and tools applied to sustainability and thus to understand early in the course of all design phases involved in a product life cycle. These studies also seek to educate students about the role that the designer has the future in relation to sustainability. The results show the complexity and importance of the selection of materials and processes for sustainability.

1.1. Design and sustainability: Life Cycle Assessment

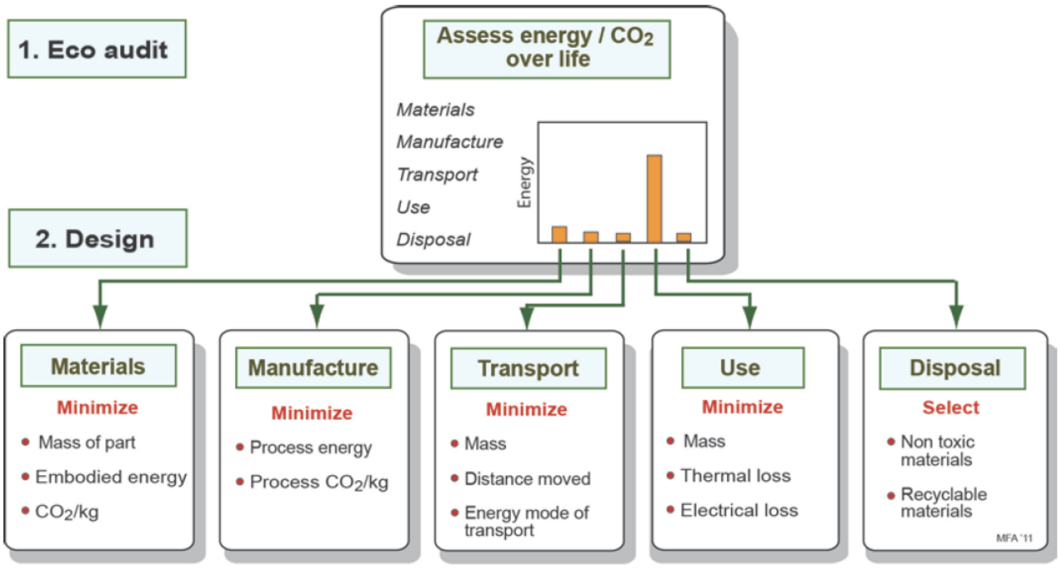
Good projects depend, among other factors, accurate information about materials, manufacturing processes and measurement of environmental impact. The selection of the suitable material is fundamental in developing the project. According to Ashby [1], Design is the process of translating a new idea or a market need in detailed information that a product can be manufactured. Each of its stages requires decisions about the materials that the product should be done and the process of doing so. Depending on the material selected, the environmental impact can become significant due to the use given to it, as well as the size and amount used.

It is usually difficult and often confusing quantifies the environmental consequences associated with materials, processes and products. Difficulties are, for example, the determination of the environmental effects associated with the objects of comparison, the almost impossible task of comparing different environmental effects and the amount of data required to compare related products. Often the required data are scarce or inaccessible, so is hard to define then analyzing environmental burden [10].

As Andrae [10], there are a number of methods and tools related to environmental assessment, such as Life Cycle Assessment (LCA) and carbon footprint, all with the intent to indicate which alternative is better compared to other. Manzini & Vezzoli [5] considers that the product should be designed, respecting, in all its phases, the concept of life cycle. It is the product from the extraction of resources necessary for the production of materials that compose it ("birth") until the last treatment ("death") after using the product. From this analysis it is possible to determine what material is the most practical during the process and as material and manufacture affects the environment.

In search of progress in the techniques of selecting materials and their interpretations or comparisons with other existing, Ashby [1] created the “maps of properties” , which gave rise to software Materials Selection, named Cambridge Engineering Selector® - CES with the support of the developers of Granta Design® [11]. This software allows you to separate the materials best suited to the proposed project, limiting them to a few units for application, after several steps of restrictions. In the 2011 version of the software, other applications have been introduced, one these is Eco Audit allowing comparison of materials counting all stages of the life cycle of the materials, figure 1. This software was chosen to be used for the Life Cycle Assessment.

Figure 1: Software ESC Edupack 2011 integrating the Life Cycle Assessment tool [12].



2. Methods

The methodology used in this study was divided into three phases:

Phase 1: Disassembly and data collection:

- Disassembly and separation of product components.
- Identification of different components, their materials and processes used.
- Weighing with a digital scale of the different components.
- Search of information materials on the manufacturer's website if haven´t an identification on the products.
- Research on the recycling of different materials to placing the data in the software.

Phase 2: Placing data in the software:

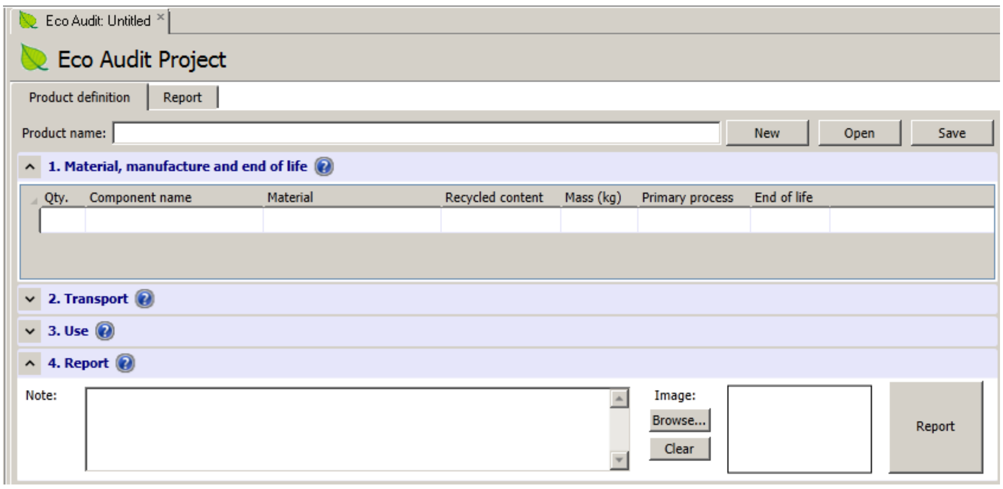
- Entering the quantity and material of each components, the percentage of recycling (0-100 %), the weight, the primary process and the final destination of the component (landfill, incineration, downcycle, reuse, remanufacturing, recycling). It was first used for the perception of the student and then research on the potential final component to our context.
- Placement of the various types of transport and their distance to each phase of the life cycle that uses transport.

- Placing of energy costs involved in the use phase of the product. In the case of squeeze the spent cooling predicting use.
- The products analyzed were: 6 Squeezes different existing models, table 1. These were chosen by the students by placing the product used this time (lifetime).
- In this phase was used the software CES EduPack 2011 with the tool Eco Audit to the Life Cycle Assessment, Figure 2.

Table 1: Squeezes analyzed and summary information placed on the software. Source: Author.

Phases of the life cycle	Squeeze "A"	Squeeze "B"	Squeeze "C"	Squeeze "D"	Squeeze "E"	Squeeze "F"
Product						
Materials	- Aluminum Alloy - PP - EVA	- PP - Neoprene - Aluminum Alloy	- PP - PET - PE	- PEAD - PS - PELBD - PP	- PET - PP - Paper	- PET - PS - PEAD
Lifetime	8 years	5 years	2 years	0,5 years (6 months)	0,25 years (3 months)	0,08 years (1 months)
Mass (kg)	0,250	0,260	0,062	0,045	0,034	0,031
Transport	Truck: 217km	Air freight: 10.140km Truck: 1200km.	Truck: 3474km	Truck: 1520km	Truck: 85km. Air freight: 10.600km. Rail freight: 185km	Truck: 419km. Air freight: 9.650km
Electricity (cooling)	192 days per year, 2 hours per day.	324 days per year, 2 hours per day.	216 days per year, 2 hours per day.	200 days per year, 1 hour per day.	90 days per year, 2 hours per day.	30 days per year, 2 hours per day.

Figure 2: Home Eco Audit in this software CES EduPack 2011 [11].



Phase 3: Analysis of the data:

- Analysis regard to energy costs in each of the phases.
- Analysis about the generation of CO_2 in each stage.
- Comparison of the different samples of each product.
- Comparative analysis of life cycle in relation to squeeze more life estimates.
- Analysis among students regarding the products analyzed and their life estimates reflecting on their consumption.

3. Results and Discussion

We presented works done at the University UNISINOS, presenting a comparative study of six types of squeezes in the market. At first the students perform the disassembly of products, in order to realize the practical difficulty of this process, the identification of components and materials of an existing product.

The software used (CES EduPack 2011, tool Eco Audit) works by measuring the energy consumption and CO_2 emissions caused by the choice of material and its manufacture, the means of transport and distance, as well as the consumption of energy in the use phase. In the case of this type of product, the energy consumption with cooling. We presented in this case study 6 different squeezes showing in Table 2 phases of the life cycle of data with energy costs and CO_2 generation.

It is noted in Table 2, the large energy consumption and consequently CO_2 squeezes of “A” and “B”. The squeeze “A” having an estimated life of 8 years absorbs this environmental impact better than the squeeze “B”, of 5 years. The consumption of energy in the use phase to be great for these two squeezes, “A” and “B”, is due to the materials used and the weight of them. As for the potential at the end of life return these energy costs and CO_2 generation, the squeeze “A” presents good results by having his body held in metal (aluminum alloy), which is recycled and thus “recover” the energy expended in production. The squeeze “B” also has a potential higher in late life, because it recycles most of the existing materials in the squeeze.

Also about the squeeze “B” production in another country to be reflected in energy consumption and CO_2 generation during transport of this product. About squeeze “C”, with an estimated short life of 2 years, has a lower energy and CO_2 generation, but has the potential at the end of life small. The squeezes “D”, “E” and “F” have a small mass in kg, which reflects the energy consumption during in materials and workmanship to be small, reflecting also the transport phase. But the squeeze “E” that has produced in another country had a high value on shipping even being lightweight. The squeeze “D” is not recycles all elements body only. The squeeze “E” it recycles all components and squeeze “F” neither component is recycled, all the components being put in landfill, which reflects the potential at the end of life being reset. These choices of components that were placed in the software are to be recycled or landfilled were student choices, common sense these students and what they would do with these products when their useful life would end.

Table 2: Comparison of energy consumption (MJ) and CO_2 generated (kg) of 6 squeezes analyzed. Source: Author.

Energy consumption (MJ) for 1 product							
Squeezes	**Material**	**Manufacture**	**Transport**	**Use**	**Disposal**	**Total (for first life)**	**End of life potential**
Squeeze "A"	20,6	2,17	0,0461	0,0578	0,175	23	-14,7
Squeeze "B"	25	5,3	21,7	0,0609	0,154	52,3	-17
Squeeze "C"	5,51	1,23	0,183	0,0163	0,0434	6,98	-3,19
Squeeze "D"	4,16	0,912	0,0319	1,67	0,028	6,8	-1,56
Squeeze "E"	2,75	0,555	3	0,846	0,0238	7,17	-1,05
Squeeze "F"	2,62	0,602	2,47	0,0591	0,00616	5,76	0
CO_2 generated (kg) for 1 product							
Squeezes	**Material**	**Manufacture**	**Transport**	**Use**	**Disposal**	**Total (for first life)**	**End of life potential**
Squeeze "A"	1,02	0,163	0,00328	0,00216	0,0123	1,2	-0,739
Squeeze "B"	0,784	0,402	1,46	0,00228	0,0107	2,66	-0,552
Squeeze "C"	0,155	0,0922	0,013	0,000608	0,00304	0,264	-0,0898
Squeeze "D"	0,14	0,0684	0,00227	0,0626	0,00196	0,275	-0,0618
Squeeze "E"	0,0867	0,0416	0,201	0,0317	0,00167	0,363	-0,0357
Squeeze "F"	0,0755	0,0451	0,166	0,000881	0,000431	0,288	0

3.1 Comparative analysis in relation to squeeze with highest life estimate

The second part of the study was to use the squeeze more life estimation, squeeze the eight years to make new analysis by placing the amount of product that would be required to use in eight years to match this first squeeze. Shown in Tables 3 and 4, the number of squeezes required at the same time spent lifetime and energy (MJ) and the generation of CO_2 for 8 years of useful life squeezes.

Table 3: Reference squeeze A and comparing the amount of product for the same lifetime. Source: Author.

	Squeeze "A"	**Squeeze "B"**	**Squeeze "C"**	**Squeeze "D"**	**Squeeze "E"**	**Squeeze "F"**
Useful lifetime	8 years	5 years	2 years	0,5 years (6 months)	0,25 years (3 months)	0,08 years (1 month)
Number of products	1	1,6	4	16	32	100

Table 4: Comparison of energy consumption (MJ) and CO_2 generated (kg) of 6 squeezes analyzed in relation to the product with the highest estimated life. Source: Author.

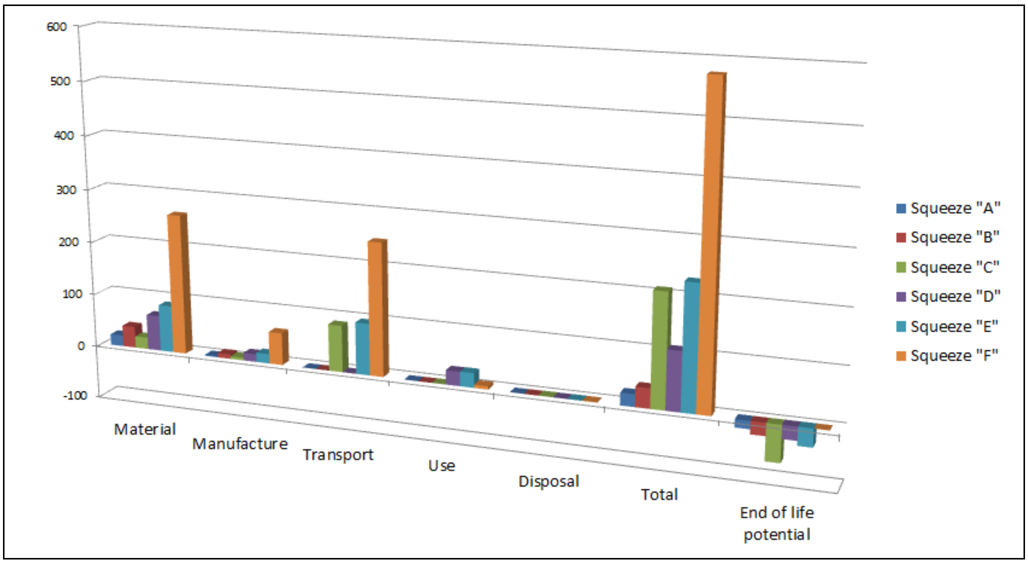
Energy consumption (MJ) for 1 product and the comparison with more products								
Quant.	**Squeezes**	**Material**	**Manufacture**	**Transport**	**Use**	**Disposal**	**Total**	**End of life potential**
1	**Squeeze A***	20,6	2,17	0,0461	0,0578	0,175	23	-14,7

1,6	**Squeeze B**	40	8,48	0,07376	0,09248	0,28	36,8	-23,52
4	**Squeeze C**	22,04	4,92	86,8	0,2436	0,616	209,2	-68
16	**Squeeze D**	66,56	14,592	0,5104	26,72	0,448	108,8	-24,96
32	**Squeeze E**	88	17,76	96	27,072	0,7616	229,44	-33,6
100	**Squeeze F**	262	60,2	247	5,91	0,616	576	0
	CO2 generated (kg) for 1 product and the comparison with more products							
	Squeezes	**Material**	**Manufacture**	**Transport**	**Use**	**Disposal**	**Total**	**End of life potential**
1	**Squeeze A**	1,02	0,163	0,00328	0,00216	0,0123	1,2	-0,739
1,6	**Squeeze B**	1,2544	0,6432	2,336	0,003648	0,01712	4,256	-0,8832
4	**Squeeze C**	0,62	0,3688	0,052	0,002432	0,01216	1,056	-0,3592
16	**Squeeze D**	2,24	1,0944	0,03632	1,0016	0,03136	4,4	-0,9888
32	**Squeeze E**	2,7744	1,3312	6,432	1,0144	0,05344	11,616	-1,1424
100	**Squeeze F**	7,55	4,51	16,6	0,0881	0,0431	28,8	0
* Squeeze reference for comparison.								

According to data obtained from the Life Cycle Assessment realizes that the first review for this change much the results, passing the squeeze that the first analysis had the lowest environmental impact, squeeze “F”, which has to be the greatest environmental impact. This is because the amount of 100 squeezes to be used in the 8 years to treat the squeeze reference. This becomes clearer in Figure 3, showing a big difference between the squeeze “F” and the others, showing the short life span of each squeeze of type “F”.

This shows the importance of the design of this product rethinking the materials selection, selecting materials with less energy consumption and CO_2 generation, higher opportunities of being recycled, lighter and easier to dismantle and other aspects.

Figure 3: Comparison chart of the 3 products analyzed in relation to energy consumption (MJ). Source: Author.



Another point highlighted in Figure 3, which makes the squeeze “F” more problematic the issue of sustainability is the potential at the end of life, be zero, in other words, has no potential to recover all the energy generated. Comparing the product with the longest estimated life of squeezes analyzed, it is possible to have a real dimension comparing their useful life. So considering these analyzes the squeeze "A", even with materials that spend more energy to produce and their manufacture, throughout his life and because of its expected life to be great, just to improve their performance in relation to sustainability.

3.2 Analysis among students regarding the products analyzed

From this type of study with students, is possible to think about the role that these future designers have in relation to sustainability. How designers can reflect on the values and lifestyle that are stimulating and disseminating on the aspirations and desires that are driving the consumer to, in a more comprehensive, inclusive and creative rethinking the old styles and create new concepts. As consumers rethink their attitudes and desires.

The salient points by the students during and after this activity Life Cycle Assessment were:

- In relation to materials, studying the amount of these, various compositions, which are aggregated to produce simple objects of day-to-day, helped them to rethink and reassess the concepts at the time of purchase.
- Questioned the amount of materials that could be better spent, with respect to time of use, that were being used in a manner not very efficient.
- Underlined the large consumption of the same product, namely the rapid exchange of products, even still being useful to the desired function, generating more unnecessary disposal of materials.
- The students said the importance of the durability of a product, so, the useful life of product to sustainability, which was reflected in the second comparative analysis between squeezes with an estimated 8 years.
- They saw and counted that simple actions with simple products can make a big help to the environment, showing the importance of conscious consumption.
- Also stressed on the importance of awareness of people and changing habits of each.
- All of these factors helped to rethink and reevaluate their concepts when buying a simple product.
- Through this the students were able to understand some aspects regarding the analysis of the life cycle of a product, suggesting that LCA was implemented in the design phase to reduce the environmental impact.

4. Conclusions

The concern and responsibility for the environmental impact made emerging new challenges for designers. While nature's resources and reduce environmental pollution increases, recycling, waste disposal and sustainable projects must be studied more seriously. Agreeing with this, it is proposed that a designer should be aware of changes and continuously look for new solutions, particularly in relation to aspects related to environmental issues.

Faced with these challenges in relation to sustainability, product design activity has been adding tools and one of them is the Life Cycle Assessment (LCA). The techniques applied to sustainability enable designers and drafters can design taking into account environmental issues. Allows the use of materials with lower environmental impact and contributes to sustainable development through the application of the proposed methodologies. Apply new methods applied to the project, studying and analyzing the life cycle of a product, benefit the environment and future generations.

Through exercises in disciplines of sustainability in design courses show up different analyzes for the same type of product, reflecting on the choice of materials and processes these. In the presented paper we reflected on sustainable consumption, exploring a tool of Life Cycle Assessment in a product of low technological complexity that was the squeeze.

The results show the complexity and importance of the selection of materials and processes for sustainability. It was important for students to analyze the different products they realize the importance of the selection of materials and the influence this has on the environmental impact.

Students were able to understand the issue of sustainability, analyzing the entire life cycle of product, it is important to highlight the different perceptions of students in relation to sustainability and the selection of materials and activities at the beginning of the end.

Students become stimulated to study more stiffness the correct selection of materials in the design phase, covering all stages of the life cycle of these products, which allowed students to visualize more clearly how you need a systemic view of the entire cycle this product life.

Thus, determining and selecting the most suitable material depends on several factors, with the design phase a crucial point, because estimating the useful life of this product becomes crucial in better selection of materials. It shows just one of the crucial points for sustainability that designers should be aware of and use these tools in conjunction with the design tools. Analyzing the product, it becomes clear how important it is the project's objectives and the target audience has been defined, so as to project the lifetime of this and thus determine the selection of appropriate materials.

Confronting consumer activity, with an estimated useful life of the product increasingly short, reflect on the selection of materials and processes appropriate to each project through the LCA provides a powerful tool to support the project, making it essential when talking about sustainability.

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Conflict of Interest

The author declares no conflict of interest.

References and Notes

1. Ashby, M. F. 1999. Materials Selection in Mechanical Design, 2nd ed.; Butterworth-Heinemann: Oxford, UK, 1999; 502 pp.
2. Karlsson, R., Luttropp, C. 2006. EcoDesign: what's happening? An overview of the subject area of EcoDesign and of the papers in this special issue. *Journal of Cleaner Production* **2006**, 14, pp 1291-1298.
3. Kindlein, W. Jr., Ngassa, A., Deshayes, P. Eco Conception et developpement: Intelligence pour la planète et nouvelles intelligences methodologiques. In *Intelligence et Innovation en Conception*

de Produits et Services, 1 ed.; Ecole Centrale de Paris. (Org.) L'Harmattan: Paris, France, 2006; pp. 359-382.

4. Ljungberg, L. Y. Materials selection and design for development of sustainable products. *Materials & Design* **2007**, 28, 466–479.
5. Manzini, E., Vezzoli, C. *O Desenvolvimento de Produtos Sustentáveis.* Editora da Universidade de São Paulo: São Paulo, Brasil, 2002; 368 pp.
6. Marques, A. C. *Análise de similares:* Contribuição ao desenvolvimento de uma metodologia de seleção de materiais e ecodesign. Mestrado acadêmico em Engenharia de Minas, Metalúrgica e de Materiais. Porto Alegre, Brasil, 2008; 127 pp.
7. Navarro, R. F. 2001. *Materiais e Ambiente.* Editora universitária UFPB: João Pessoa, Brasil, 2001; 180 pp.
8. Platchek, E. R., Schaeffer, L.; Kindlein, W. Jr.; Cândido, L. H. A. Methodology of ecodesign for the development of more sustainable electro-electronic equipments. *Journal of Cleaner Production* **2007**, 16, 75-86.
9. Silva, E. S. A. *Um sistema Informacional e perceptivo de Seleção de Materiais com enfoque no Design de Calçados.* Mestrado Profissionalizante em Engenharia ênfase: Engenharia Ambiental e Tecnologias Limpas. Porto Alegre, Brasil, 2005; 105 pp.
10. Andrae, A. S. G. *Global Life Cycle Impact Assesments of Material Shifts:* The example of a Lead-free Electronics Industry. Springer: London, UK, 2010; 183 pp.
11. Cambridge engineering selector CES - EDUPACK 2011 (software), GrantaDesign: Cambridge, UK, 2011.
12. Ashby, M. F., Coulter, P., Ball, N.; Bream, C. 2011. The CES EduPack Eco Audit Tool - A White Paper. Granta Design Ltd. Version 2: Cambridge, UK, 2011; 23 pp.