Life Cycle Thinking in Brazilian Mechanical Engineering and Post-Graduation Courses

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Introduction

Life Cycle Assessment (LCA) has shown to be an important scientific framework. While considering Mechanical Engineering activities, LCA can help in: i) including environmental aspects in design and development of products, ii) design and operation of industrial process, iii) choosing materials, iv) design considering energy efficiency, distribution, packaging, use and end-of-life[1].

The National Education Council decided that all engineering courses must include Environmental Science as a discipline, however just some of them should take into account Environmental Management[2]. These courses do not normally include disciplines or topics as Life Cycle Assessment (LCA), not even Life Cycle Thinking (LCT).

In 2001, it was proposed an elective discipline of Industrial Ecology at the Industrial Mechanical Engineering Course at CEFET-PR. Since the second semester of that year, the discipline is being attended. Several other post-graduation courses also adopted Life Cycle Assessment or Design for the Environment as disciplines.

To give rise to the importance of using LCA and to verify if students do consider LCT while performing decisions, an exercise was developed and applied in three different courses: i) undergraduated (Industrial Mechanical Engineering and Environmental Chemistry), ii) *latu-sensu* postgraduation (Environmental Management and Environmental Engineering) and iii) *strictu-sensu* postgraduation (Mechanical Engineering and Materials Post graduated).

Methodology

In order to verify if students consider life cycle thinking while performing his activities, the proposed exercise was divided in 5 pieces, each one corresponding to a life cycle stage (extraction, transportation, manufacturing, use and disposal). Each piece is distributed to a group.

Two approaches were performed: the first one was without any previous explanation; ii) the second approach was performed after a discussion about individual and group optimum.

The aim of each piece was to select which kind of product should be produced to obtain the less environmental problems considering only one environmental impact**.** Two products were considered, each of them could be obtained from two different materials: M_1 or M_2 which can be used to produce product P_1 and M_3 or M_4 to obtain product P_2 as shown in Figure 1. For

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[1] Graedel TE, Allenby BR Industrial Ecology . Prentice Hall. New Jersey. 2003. 363p.

[2] CNE (Conselho Nacional de Educação) 2002 Resolução CNE/CES 11, de 11 de março de 2002. 3p.

each material, it was necessary to choose the equipments, which were related to emissions of two pollutants, named *X* and *Y*, both responsible for the same environmental impact, *I*.

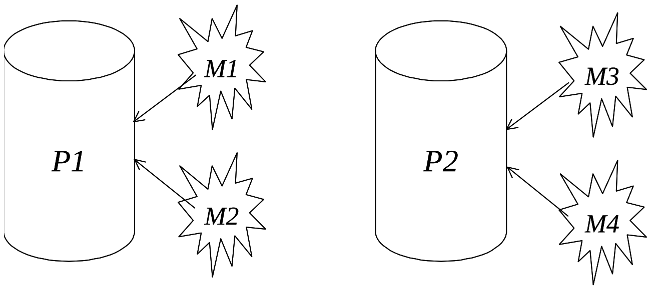

Figure 1: Materials and Products

In Figure 2 it is an example for the extraction phase. Each bullet shows the equipment, so that, to produce M_1, three equipments are needed: *a*, *b* and *c*.

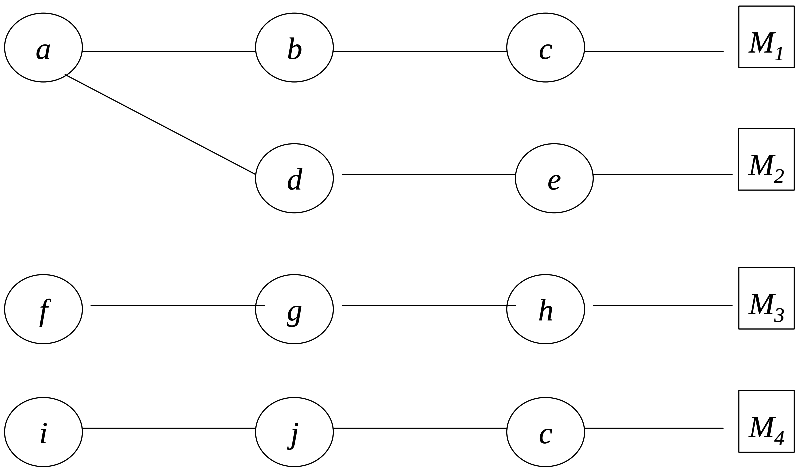

Figure 2: Equipments to produce each material

In each piece, there were two signs that there was a relationship between all the pieces, as shown in Figure 3: the number of the group and, in the text, there was an evidence that the group was related to other life cycle steps.

Figure 3 also shows two tables: one that contains the necessary equipments to manufacture each material and the second within the emissions of the equipment in kilograms, per kilogram of material.

All other pieces were similar to the one presented in Figure 3, differing the necessary equipments and emissions.

The second part of the exercise consisted in using characterization factors to calculate environmental impact *I*, which was given to the students later.

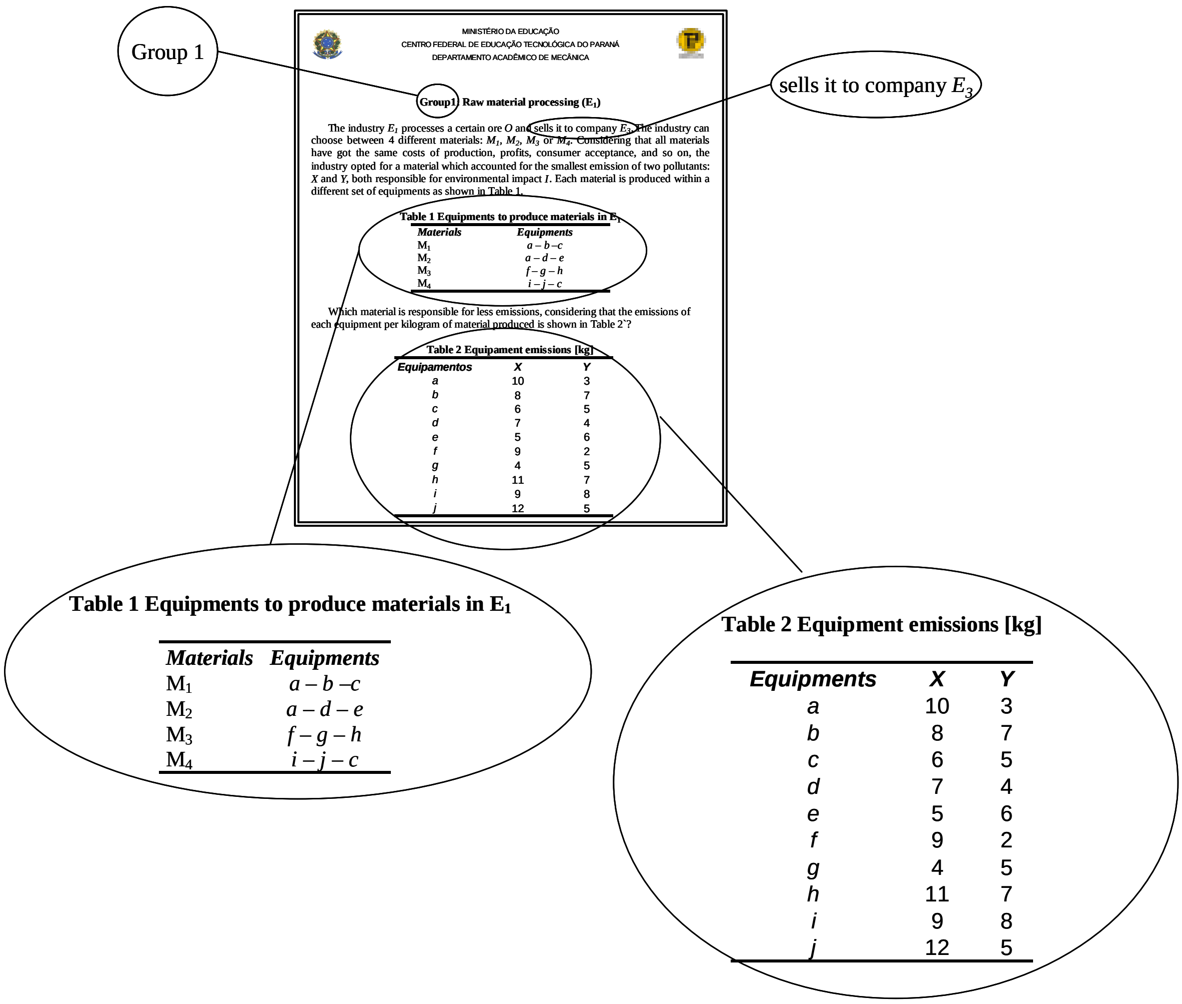

Figure 3 Sheet of exercise

Results

This exercise has been performed since 2001 for 259 undergraduated and post graduated students as shown in Table 1. The first approach was applied in 34% of the sample.

Table 1 Number of students who performed the exercise

Level of the students	Year			
	2001	**2002**	**2003**	**2004**
Undergraduated	**10**	**35**	**27**	**9**
Mechanical Engineers	10	35	7	9
Environmental Chemistry	-	-	20	-
Post graduated	**-**	**71**	**82**	**25**
Latu sensu	-	*63*	*77*	*20*
Environmental management	-	20	20	20
Environmental engineering	-	43	57	-
Strictu sensu	-	*8*	*5*	*5*
Total	**10**	**106**	**89**	**34**

It was interesting to notice that only some groups were in doubt about summing up the emissions of *X* and *Y*. Most students knew that this sum could not be performed. All groups selected the materials separately, no matter the approach, no matter the level of the students and no matter the course. The results obtained by them are presented in Table 2.

Table 2: Results obtained from the students

Group	Life cycle stage	Material selected for X	Material selected for Y
1	Extraction	M_2	M_2
2	Transportation	M_4	M_1
3	Manufacturing	M_4	M_4
4	Use	M_2	M_2
5	Disposition	M_1	M_1

A discussion about the importance of considering life cycle emerged: how can a consumer choose material M_2 if the product manufacturer will only produce with M_4? To the students who discussed previously about individual and global optimum, the surprise was not so big, however the rest was chocked and they had realized that a whole new world was in front of them.

It was also awesome to notice the difficulties to solve the problem. Some of the students suggested in the first place that it should be selected the material that appears more often, that is M_2, even though they had all the data. A minority part of the group realized that they should join all the information to select the material. This has been performed and the results are presented in Figure 4. The biggest surprise of everybody was that there was still a doubt between M_3, which emits less X and M_2, that emits less Y.

A new discussion about the relevance of taking life cycle into account involved the class: after performing such a lot of calculations and considering all the data necessary to perform a LCA, they were still in doubt: is LCA helpful? At last, to solve that problem, it was presented characterization factors: each Y emitted was equivalent to the emission of 20 X, so that it was finally possible to select the best material, while considering I: M_3.

At this point, students were very satisfied within the methodology and they showed a lot of interest in learning about the specific points of life cycle assessment, which was presented during the semester.

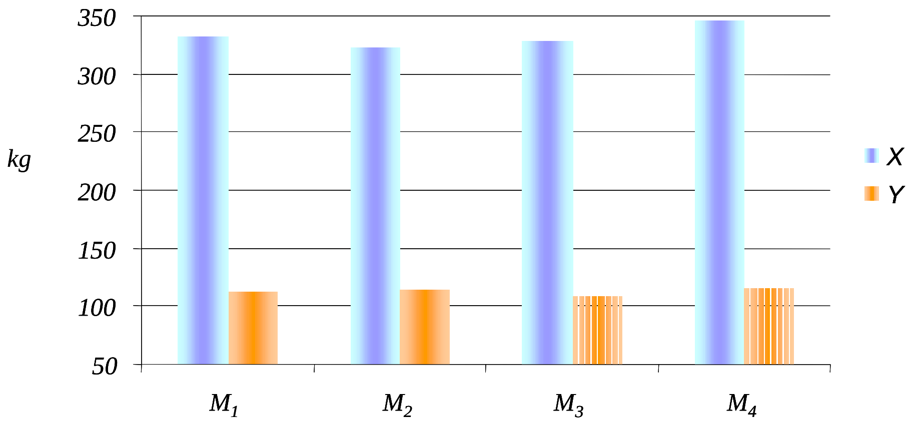

Figure 4 Inventory results

Conclusions and Suggestions

The use of the exercise showed that undergraduated and post graduated students at Paraná do not take into account life cycle thinking while performing decisions. Nevertheless, engineers are responsible for the development of products and process. Several post graduated students are also taking decisions or developing technical information to help managers in their decisions.

It is therefore suggested that undergraduated and post graduated courses include LCA as a mandatory topic. As a result, at CEFET-PR, a technological course (Mechanical Technology) has now LCA in its curriculum.