International Journal of Engineering Education Vol. 32, No. 4, pp. 1719–1731, 2016
Printed in Great Britain
0949-149X/91 $3.00+0.00
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The Role of Eco-design Education in Influencing the Design of Electrical and Electronic Equipment: A Case Study Involving Industrial Design Engineering Students*

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The purpose of this paper is to analyse the influence that environmental education in eco-design has on industrial design engineer students facing the design of electrical and electronic toys. From the designer's perspective, eco-design education improves the extent to which environmental requirements are incorporated into the design process of electrical and electronic equipment, thus allowing for the development of products with enhanced environmental performance and greater potential for reuse or recycling. Taking electrical and electronic toys as a target product category, a workshop intended for students of bachelor's and master's degrees related to Industrial Design Engineering, was organized in a Spanish University. The main objective was to determine the extent to which designers include environmental recommendations into the process of designing their products and what type of recommendations they incorporate. In addition, this study determines differences among students from different educational profiles and analyzes the willingness of designers and future designers to participate in this kind of initiatives. The results suggest that training designers in the end-of-life of products and their environmental issues in a practical way makes them more willing to incorporate environmental requirements into the design process of electrical and electronic toys.

Keywords: engineering education; electrical and electronic toys; end-of-life; industrial design

1. Introduction

The European regulatory framework applicable to Waste Electrical and Electronic Equipment (WEEE) is provided by Directive 2012/19/EU [1], by establishing obligations for the different stakeholders involved in the life cycle of this kind of waste. This European legislation establishes that, among other aspects, WEEE needs to be collected selectively and managed in an appropriate manner. It also states the desirable target percentages of recovery and reuse and recycling of components, and materials.

This study is focused on electrical and electronic toys, belonging to Category 7 (toys, leisure and sports equipment) until 15 August 2018 and Category 5 (small WEEE (S-WEEE)) from that date onwards. In recent years, the consumption of electrical and electronic toys has grown exponentially, due to both accelerated technological progress and the new needs of users. The growing demand for devices that incorporate multimedia for child or young audiences has sped up the incorporation of electrical and electronic components in toys as it attempts to adapt traditional ones to this new reality. However, most of these toys are produced as temporary products that are not intended to be durable or adaptable to the growth of children. The same occurs with other products belonging to other WEEE categories, which are not designed and manufactured taking their upgradeability and reuse requirements in mind [2].

From the designer's perspective, end-of-life (EOL) requirements are not currently taken into account during the design process of toys and, therefore, electrical and electronic toys have generally complex disassembly sequences, difficult access to electrical and/or electronic components and a wide variety of incompatible materials, which hamper their potential for recycling and reuse [3]. This is mainly due to a lack of knowledge by designers about the potential valorisation processes applicable at the EOL of kind of products.

This paper describes an experience based on a workshop focused on the incorporation of end-of-life considerations into the design of electrical and electronic equipment. The aim was to explore the effect that the integration of such specific training in the curricula of industrial design-related degrees had on the willingness of designers and future designers to incorporate environmental requirements into the design process of electrical and electronic toys.

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* Accepted 1 June 2016.

2. Background

The awareness of environmental problems and sustainability and the relevance of their implication in higher education are issues that have continued to grow in the last decade [4–6]. According to Lidgren et al. [7], students are considered to be one of the key stakeholders in higher education for sustainable development. Recently, some work has focused on considering the university as a key organization that could promote education for the environment [8, 9]. Karatzoglou [10] reviews relevant worldwide university projects carried out in this field.

In the case of Spain and from the perspective of the student and his or her training, the White Paper on Environmental Education [11] establishes the need to implement environmental competences in university curricula, thereby allowing students to develop their environmental attitudes and behaviour.

Environmental issues play a relevant role at universities, where tomorrow's leaders, entrepreneurs, decision-makers and scholars are prepared [12]. Students have an important influence on the future state of the environment, which makes the incorporation of competences related to the environment and sustainability into education even more relevant [13, 14]. The need for incorporating environmental skills and sustainability or eco-design attitudes into engineering design degrees has been studied broadly in the literature [15–21]. As Zsóka et al. [22] reported, for environmental education to be successful, strengthening responsibility is definitely a key, both in high school and at university, where innovative approaches are required to effectively prepare students to deal with environmental issues. This implementation at university level is especially important in the case of degrees related to industrial design, since the environmental impact of a product/service depends on decisions that designers take at early stages of its design process. To demonstrate the importance of that implementation, Lau [23] developed new introductory projects in the first-year engineering design course in order to emphasize green design.

Industrial designers act as a bridge between the consumer's cultural sphere and the world of production providing a key link in ensuring that the needs of customers are also central in the development of new technology [24]. Beyond the value of industrial designers in the development of new products, designers can also stimulate the creation of new knowledge by producing artefacts to test ideas and aid understanding [25], so designers play also an important role in scientific research where concepts such as environment and sustainability are often highlighted. Based on a results from a survey aimed at 125 schools of art and design in North America about design education [26], sustainability was identified as a priority for research by 80% of respondents. The collaboration between designers and scientist has been extensively studied by Rust [27].

Since designers play the role of the main actor in the product development process [28] and they are crucial in the radical change required to achieve a sustainable society, design educators must recognize this as a primary goal [29]. As claimed by Boyle [30], professions which are involved in product or process design require more understanding of life cycle assessment and design for the environment to enable them to take such concepts into account during the design process. With this approach, they must consider the potential consequences and impact of their proposals in order to, at least to some extent, anticipate potential problematic and emerging issues [31]. In this context of creating sustainable futures, designers and educators have a common and unique role to play in helping people to envision new realities [32].

Ecodesign is defined by Directive 2009/125/EC [33] as the integration of environmental aspects into product design with the aim of improving its environmental performance throughout its whole life-cycle. Ecodesign includes the development of products which are more durable and energy efficient, avoid the use of toxic materials and can be easily disassembled for recycling [34–35]. In this field, designers play an important role, due to their position in the early stages of the product development process [36] and to the fact that they create relationships between products and consumers, by giving them alternatives when it comes to disposal/re-use/etc. As Lobos and Babbitt [37] stated, one strategy to avoid consumption based on short product life cycles is the integration of emotional attachment and the technological adaptability of the product, thus preventing technological obsolescence. In the field of electrical and electronic toys, the incorporation of both strategies could be especially interesting, since both the emotional factor and technology are the two main characteristics of this kind of products. Toys such as puzzles, board games, dolls or sound and light toys are being reinvented with integrated electrical and electronic components which were not present before [38]. All these new incorporations should be carried out taking the toy's end-of-life into account.

In Spain, some trials focused on improving the EOL context of toys have been conducted. Fullana et al. [39] carried out a project where ecodesign tools and strategies for the toy industry were worked out and applied. Muñoz et al. [40] defined general ecodesign measures for the toy sector in Catalonia by applying Life Cycle Assessment (LCA) on a toy incorporating electrical and electronic components. Solé et al. [41] conducted a pilot project for the recovery and recycling of toys. The results they obtained from several campaigns run between 2007 and 2009 showed that a significant number of toys could be repaired and/or reused. Pérez-Belis et al. [3] characterized and disassembled a representative sample of electrical and electronic toys obtained from a campaign in which 1 t of waste electrical and electronic toys were collected from different Spanish educational centres. Sixty-five per cent of the toys collected worked properly, so they had a significant potential for reuse.

This entire theoretical and practical framework related to environmental issues is relevant for the product design process and should be integrated into regular engineering courses through specific training workshops. The way to achieve this has been discussed in the literature [42], which also describes experiences on the matter. In addition, a research project about ecodesign tools for designers [43] shows that a combination of guidance, education and information, along with well-considered content, appropriate presentation and easy access are all critical aspects to the success of the integration of environmental issues into the designer's work.

Since some of the projects were successful at stimulating and encouraging students to integrate fundamental environmental design principles [44], this paper proposes a case study based on a workshop aimed at analysing whether environmental education improves the designer's willingness to incorporate environmental requirements into the process of designing electrical and electronic toys.

3. Design of the workshop

Taking electrical and electronic toys as a target product category, a workshop entitled "Incorporation of the end-of-life into the design of electrical and electronic equipment. Application to Category 7 (Toys)" was conducted at Universitat Jaume I (Spain) in order to:

- determine the extent to which designers include environmental recommendations into the process of designing their products and what type of recommendations they incorporate,
- determine the differences among students from different profiles in terms of ecodesign and,
- analyze the willingness of designers and future designers to participate in this kind of initiatives

The workshop was mainly intended for students of bachelor's and master's degrees related to Industrial Design Engineering, with a distinction being made among the following profiles:

- Profile 1: 2nd year students of the Bachelor's Degree in Industrial Design Engineering, who had not yet studied any specific ecodesign subjects.
- Profile 2: 3rd year students of the Bachelor's Degree in Industrial Design Engineering, who had completed a specific subject dealing with ecodesign.
- Profile 3: Bachelor's Degree in Industrial Design Engineering postgraduates who were currently enrolled in a Master's Degree in Product Design and Manufacturing and had completed another advanced subject related to design for the environment and recycling, in addition to the ecodesign subject from the Industrial Design Engineering degree.

The sequencing of the workshop is shown in Fig. 1 and its different stages are outlined below.

1. Explanation of the workshop and its contents. The objective was to provide all workshop participants with information (slides, videos, pictures, etc.) about the WEEE framework: legislation, WEEE identification and collection, facilities for WEEE treatment, alternatives oriented towards the reuse of WEEE, etc., with special emphasis on electrical and electronic toys. For further activities, participants had all this information printed out on paper. According to Lofthouse [43], examples which are based on reality are really helpful for designers to be able to integrate ecodesign in their projects.
2. Workgroup formation. The goal was to divide the group into small workgroups consisting of 4 or 5 students. The remaining activities were carried out by those groups. Groups were randomly created in order to mix different profiles.
3. Approaching the goals of the workshop. This activity had two main objectives. On one hand, it should serve as a means of establishing initial contact between participants and the purpose of the workshop and, on the other hand, it should balance the level of knowledge possessed by all the participants. To achieve this, the first activity proposed for each working group was to analyse and discuss the problem of WEEE management and its application to electrical and electronic toys (based on information explained by the workshop moderators and provided on paper). In order to provide the information in a creative and attractive way for students, a specific newspaper about electrical

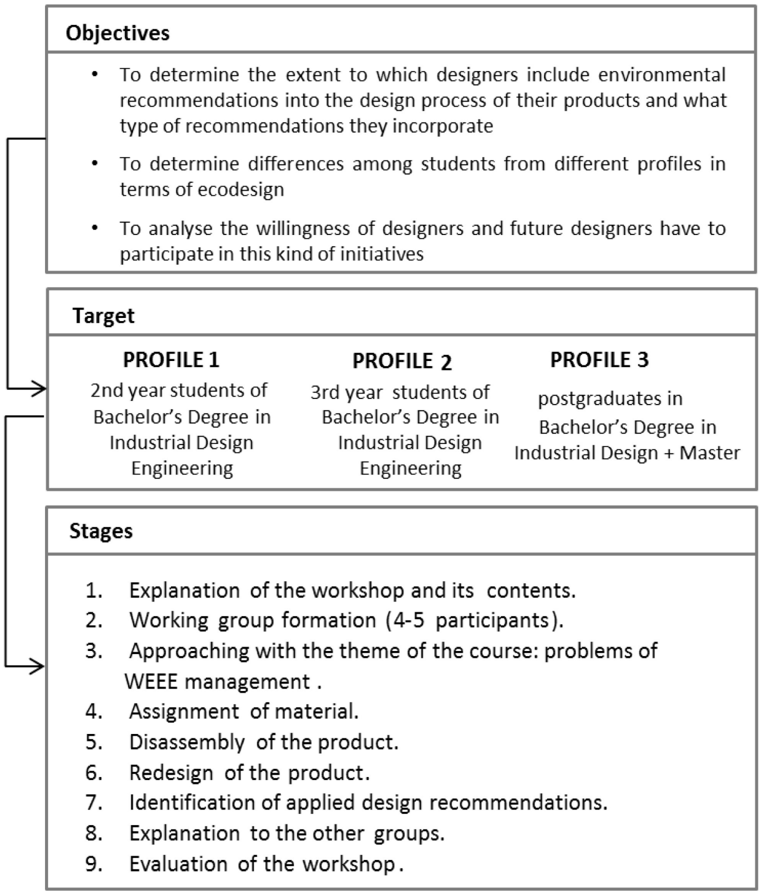
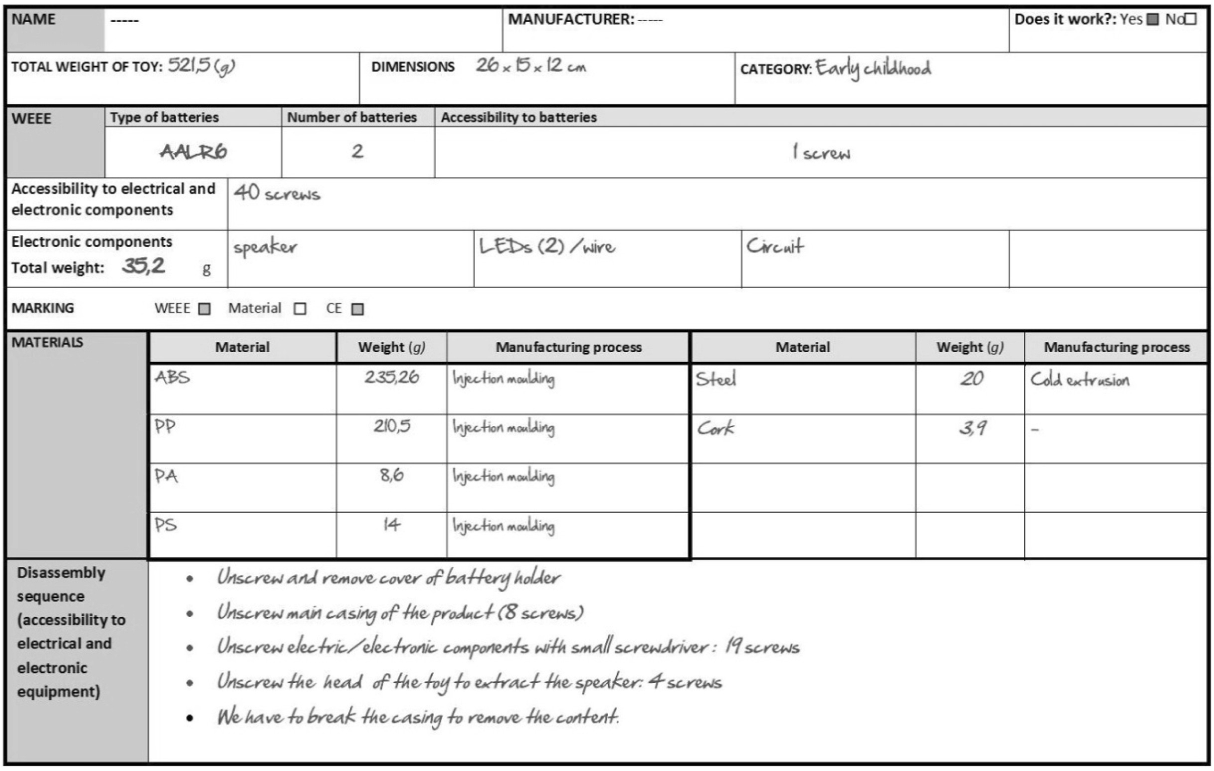


Fig. 1. Overview of the workshop.

and electronic toys was developed. It was designed including real content related to consumption, disposal, sales and management of electrical and electronic toys.

4. Assignment of material. Each working group was provided with a waste electrical and electronic toy, tools for disassembling it and other supplementary materials (screwdrivers, pliers, scissors, etc.) for them to use in the following activities.
5. Disassembly of the product. This activity represented the main part of the workshop. The goal was to redesign the toy that had been allocated to each working group, bearing in mind the information provided and discussed in the previous activities. Each working group had to perform the following tasks:
   - Disassemble the electrical and electronic toy using the tools provided, in order to analyse the sequence of disassembly needed to separate its electrical and electronic components (batteries, plastic containing brominated flame retardants, external electric cable, capacitors, printed circuit boards, switches or backlighting lamps), as established by current legislation. The disassembled materials/components were then identified and weighted.
   - Fill in the form about the disassembly sequence of the toy, providing information about the following aspects: the name of the product, its category, the type, number and accessibility to batteries, its disassembly sequence and components, both electrical and electronic and non-electrical and non-electronic components, etc. As an example, a completed disassembly form is shown in Fig. 2.
6. Redesign of the product. The goal at this stage was to redesign the toy taking into account the information provided about the end-of-life of WEEE. To do so, students could produce a physical redesign using the supplementary material made available to them or rely on conceptual sketches.
7. Identification of applied design recommendations. The goal was to identify the design recommendations that each working group had applied during the redesign process. To do so, they had to select the recommendations that had been included in their own redesign from the list of design recommendations sug-



NAME	-----	MANUFACTURER: -----	Does it work?: Yes ■ No☐
TOTAL WEIGHT OF TOY: 521,5 (g)	DIMENSIONS 26 x 15 x 12 cm	CATEGORY: Early childhood	

WEEE	Type of batteries	Number of batteries	Accessibility to batteries
	AALR6	2	1 screw
Accessibility to electrical and electronic components	40 screws		
Electronic components Total weight: 35,2 g	speaker	LEDs (2) / wire	Circuit
MARKING	WEEE ■ Material ☐ CE ■		

MATERIALS	Material	Weight (g)	Manufacturing process	Material	Weight (g)	Manufacturing process
	ABS	235,26	Injection moulding	Steel	20	Cold extrusion
	PP	210,5	Injection moulding	Cork	3,9	-
	PA	8,6	Injection moulding			
	PS	14	Injection moulding			

Disassembly sequence (accessibility to electrical and electronic equipment)

- Unscrew and remove cover of battery holder
- Unscrew main casing of the product (8 screws)
- Unscrew electric/electronic components with small screwdriver: 19 screws
- Unscrew the head of the toy to extract the speaker: 4 screws
- We have to break the casing to remove the content.

Fig. 2. Example of completed product form with information of the disassembly.

gested during the workshop. The proposed design recommendations are classified according to the Ecodesign Strategy Wheel of Brezet and van Hemel [45]. While some of these recommendations come from the physical characterization of a representative sample of electrical and electronic toys [3], others have been adapted from the environmental requirements of some ecolabelling systems focused on toys [46-51]. In addition to this, more recommendations may be added if needed. This activity will provide the results needed to achieve objective 1 of the workshop, which is concerned with the extent and type of environmental recommendations that designers include in the design process of their products.

8. Redesign sharing session, with the aim of presenting the results, rationale and conclusions of each working group to the remaining participants.
9. Evaluation of the workshop. The goal was to determine how much participants had learnt about the application of design recommendations to the redesign of electrical and electronic products and their willingness to apply them in future designs. To do this, a questionnaire was developed to compare their knowledge before and after the workshop. Hence, at the end of the workshop each participant had to answer the questions shown in Table 1 on a scale of 1 (No, nothing) to 5 (Yes, in depth). According to objective 2, this activity will determine the differences among the profiles in terms of ecodesign knowledge. In addition, the willingness of designers to participate in this kind of initiatives (objective 3) will be assessed through the number of participants who attended the workshop. Moreover, Question 7 will show whether the workshop has fulfilled their expectations.

4. Results

Following the method described in the previous section, the workshop was held at Universitat Jaume I (Castellón, Spain). It was attended by 25 participants (maximum capacity of the workshop) with the following profiles: 40% profile 1 (2nd year students of the Bachelor's Degree in Industrial Design Engineering), 40% profile 2 (3rd year students of the Bachelor's Degree in Industrial Design Engineering) and 20% profile 3 (student of the Master's Degree in Product Design and Manufacturing).

After the initial presentation and explanation of the workshop and the problems associated with the management of WEEE, the current management of waste from electrical and electronic toys and so forth, the 25 participants were organized into 6 groups of 4–5 participants. Each of them was assigned a toy belonging to a different category, as

Table 1. Evaluation questions for each student

		Before workshop					After workshop				
		1	2	3	4	5	1	2	3	4	5
Q1	Do you know what Design for End Of Life (EOL) is?										
Q2	Do you think that EOL design recommendations are necessary?										
Q3	Have you ever incorporated or are you going to incorporate EOL recommendations in your designs?										
Q4	Do you know WEEE Directive?										
Q5	Do you know that electrical and electronic toys must be managed as specific waste as the rest of electrical and electronic equipment (household appliances, computers, etc.?										
Q6	Do you know how a plant of e-waste recycling works?										
Q7	Has the workshop fulfilled your expectations?										

Table 2. Working groups and product category

Group	N° participants	Product category
A	4	Early childhood
B	4	Small-sized vehicles
C	4	Small-sized vehicles
D	4	Early childhood
E	4	Electronic board games
F	5	Electronic board games

Table 2 shows and they were given information on paper together with tools for disassembling and redesigning the toy. One of the aims of this action was to emphasize the importance of practical and entertaining experience as a means to provide several opportunities for learners to obtain valuable insights [52–54].

After disassembling the toy, each working group filled in the form shown previously as an example in Fig. 2, which served to identify aspects to be improved during the redesign of the toy, such as the number of screws that had to be removed to access the electrical and electronic contents, systems for disassembling the product, difficulty involved in

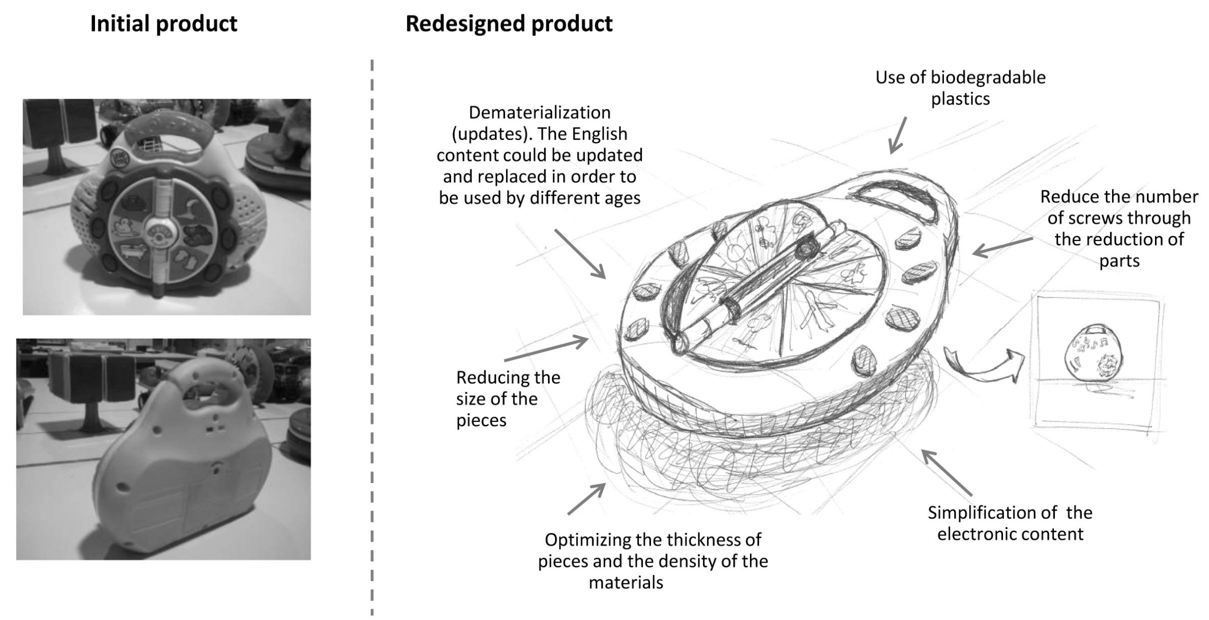


Fig. 3. Example of a redesigned electrical and electronic toy during the workshop.

the disassembly, compatibility of materials of the product, etc.

Each group then redesigned their toy applying different ecodesign recommendations and taking into account the disadvantages identified during the disassembly process of the original toy. An example of a redesign case is shown in Fig. 3.

Table 3 offers a summary of the design recommendations they were provided with and shows those which working groups with the same product agreed on.

According to these results and with regard to the first objective, it could be observed that all working groups had incorporated design recommendations into their projects, 57% of which were EOL recommendations, such as reducing the number of screws or avoiding combinations of incompatible plastics. In general, designers found that electrical and elec-

Table 3. Ecodesign recommendations by toy category (partial)

7.1	**Early childhood**	**Group A**			**Group D**		
		Low	**Medium**	**High**	**Low**	**Medium**	**High**
1	Use of biodegradable plastics			x			x
2	Use plastic materials instead of metal			x		x	
3	Reduce the number of screws through the reduction of parts			x			x
4	Simplify the electronic content			x			x
5	The electronic boards must be made with Surface Mount Device (SMD).			x		x	
6	Reducing dimensions of electrical and electronic components			x			x
7	Reducing the size of the pieces	x				x	
8	Reusable packaging design	x					x
9	Use recycled paper in the packaging	x					x
10	Do not use compounds to give the paper optical bright	x					x
11	Mechanical elements instead of electrical	x			x		
12	Multifunction			x			x
..	.. continues* ..						
7.5	**Small-sized vehicles**	**Group B**			**Group C**		
		Low	**Medium**	**High**	**Low**	**Medium**	**High**
1	Reducing the number of screws through the reduction of parts			x		x	
2	Avoid mixing of incompatible plastics recycling			x		x	
3	Marked or tagged by injection plastic identification			x			x
..	.. continues* ..						
7.6	**Electronic board games**	**Group E**			**Group F**		
		Low	**Medium**	**High**	**Low**	**Medium**	**High**
1	Dematerialization (upgrades or updates)		x				x
2	Optimizing the thickness of pieces and the density of the materials		x				x
3	Reducing the number of screws through the reduction of parts			x			x
4	Optimize the dimensions		x				x
5	Add solar energy functions		x				x
6	Simplification and minimalism			x		x	
..	.. continues* ..						

* It only shows the recommendations which have agreed the groups that analyzed the same product.

tronic toys, as well as other small devices, had not been manufactured with their disassembly and potential reuse in mind. As regards the product categories, the following results were obtained:

- "Early childhood" category had a greater margin for environmental redesign than the other categories. Both groups analysing this category (Table 2) agreed on the need to incorporate eight recommendations into their redesigns.
- "Small-sized vehicles" category should reduce the number of screws and identify the materials used.
- "Electronic board games" category noted for the difficulty involved in its disassembly, since they had a large number of screws, different size screws and different types of connections. This is why designers defended the idea that, on one hand, it is necessary to reduce the number of pieces, their dimensions and the number of screws, which in turn reduces the amount of material used. And, on other hand, they also noted that, due to the high electricity consumption while they are in use, these toys should incorporate systems that utilize solar power or other renewable sources of energy.

The level of intensity with which designers incorporated these recommendations into their projects was high in 33% of cases (Table 3). Notable examples included the use of biodegradable plastics, simplification of electronic content, multifunction toy design, the incorporation of plastics identification in the injection mould and reducing the number of screws by lowering the number of parts the toy is made up of.

Once the workshop had ended, each participant individually completed the survey shown in Table 1. In accordance with other studies [55], we must first know the designer's initial knowledge regarding the environmental issues analysed, as a way of setting a starting point for the learning process and to establish a reference for evaluating the experience. The results are shown in Fig. 4, the average being indicated on a scale of 1 (No, nothing) to 5 (Yes, in depth) for each question and for each profile.

With regard to the second objective and according to the results shown in Fig. 3, the following behaviour was observed:

- Profile 1, students in their 2nd year of the Bachelor's Degree in Industrial Design Engineering, who had not yet studied any specific ecodesign subject, presented basic notions about what design for end-of-life is, an issue that they understood much better when the workshop ended.

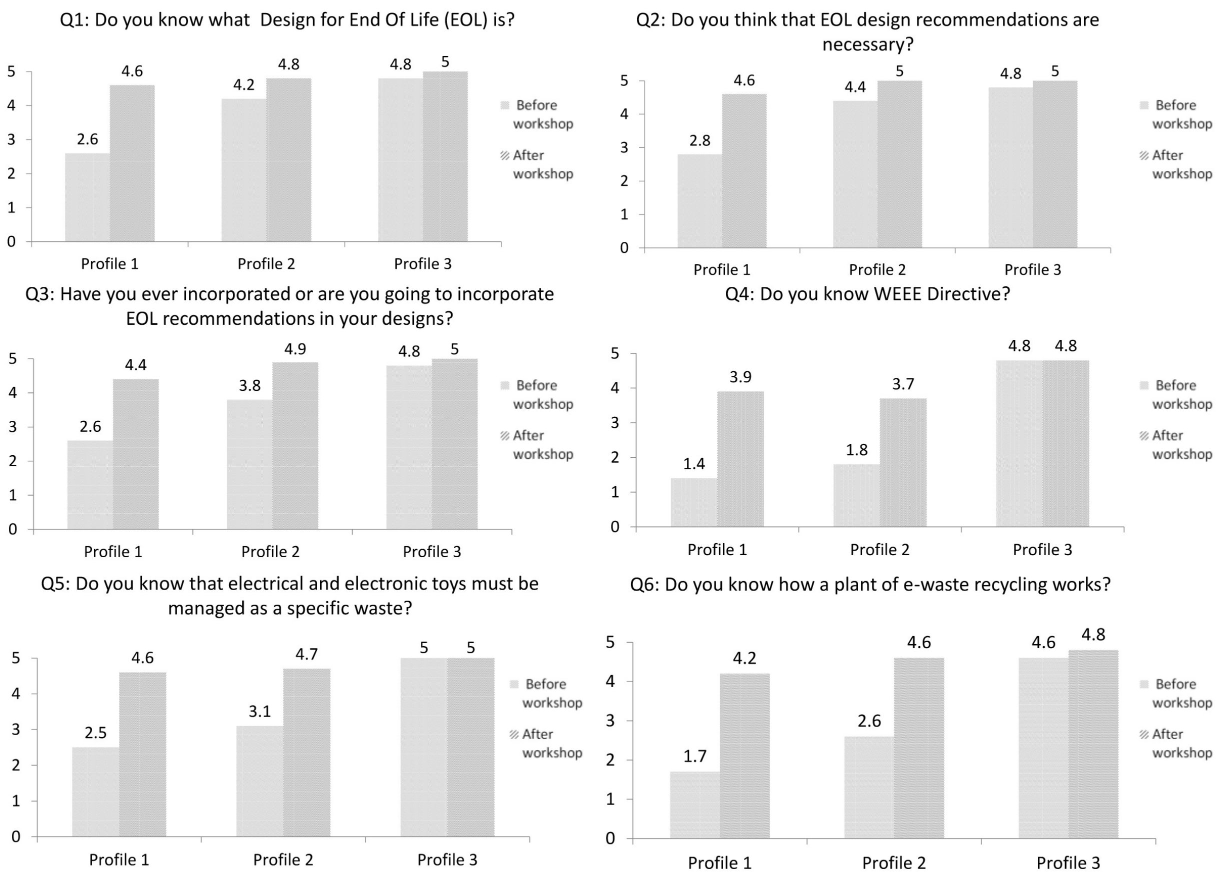


Fig. 4. Results of the evaluation of the knowledge of each profile before and after the workshop (detailed by question).

Regarding the second question, they granted a certain amount of importance to the end-of-life recommendations, but it was not until the end of the workshop when they perceived them as a necessary part of the design of the product. Before the workshop, students had not previously considered these recommendations but by the end of the workshop they were willing to integrate them. On the basis of the answers analysed in the fourth question, it can be noted that this profile had no information concerning the WEEE Directive and in spite of increasing this information during the workshop, they were not completely sure they understood it in depth. Question 5 shows that the students sensed that this waste should not be disposed of in the traditional container, but they did not know that it needs to be managed specifically, like the other WEEEs. Question 6 shows how participants in this profile did not know how an electronic recycling plant operated. This knowledge increased substantially after viewing an explanatory video about the operations carried out in these e-waste recycling plants. Therefore, we conclude that Profile 1 had the theoretical fundamentals of EOL design, very few basic notions about the legislation and specific management of electrical and electronic toys and very little knowledge about practical information such as the operations performed in an e-waste recycling plant. In conclusion, the general knowledge of Profile 1 at the beginning of the workshop was lower than the average recorded for the whole course on all the questions and it also remained lower at the end of the workshop.

- Profile 2, consisting of students in their 3rd year of the Bachelor's Degree in Industrial Design Engineering, who had completed a specific subject on ecodesign, started with a higher level of knowledge than students with Profile 1. First of all and in reference to question 1, they claimed to know the meaning of EOL design and had an even better knowledge of it after the workshop. Unlike Profile 1, they considered EOL recommendations important and they had integrated them into most of their projects. They also stated that they would integrate them more after the workshop. As evidenced by the results from question 4, this profile did not know about the WEEE Directive and although they possessed some basic knowledge after the workshop, they did not have a good command of the matter. On the other hand, in question 5, which dealt with the specific management of WEEE toys, their answers revealed that they did not know their specific management obligations, although by the time the workshop finished they were more familiar with the issue. In conclusion, Profile 2 started the workshop with greater knowledge than Profile 1, with a level above the average of the course, except in questions 4 and 6. This profile knew about EOL design and design recommendations, although their knowledge about WEEE legislation and practical information was lower.
- Profile 3, that is, Bachelor's Degree in Industrial Design Engineering postgraduates enrolled in a Master's Degree in Product Design and Manufacturing, was the profile with the highest level of knowledge. In addition to an ecodesign subject from the Industrial Design Engineering degree, they had also completed another advanced subject related to design for the environment and recycling. For these graduate students undergoing a process of specialization, the amount of knowledge they obtained from the workshop was significantly lower than in the case of the other student profiles, which is proof of their higher level of training. This can be seen in the results obtained for questions 1, 2 and 3 about EOL design and recommendations. All of them presented a high level of knowledge before and after the workshop, which means that they were familiar with design recommendations and they had integrated them into their projects. With regard to question 4, these students had a broad working knowledge of the WEEE Directive from the beginning and so the workshop did not contribute to increase this knowledge. They had in-depth knowledge about the specific management of toys and the operations of an e-waste recycling plant, but the workshop had also increased this information. In conclusion, the level of knowledge of Profile 3 was above the general average, both before and after the workshop, with an in-depth awareness of the three main areas of the workshop: EOL design and recommendations, WEEE legislation and WEEE recycling systems.

To conclude the evaluation of the workshop, Fig. 4 shows the percentage of improvement of the knowledge of each profile for each question, based on the difference between their knowledge before and after the workshop. Percentages have been calculated on a scale of 1–5, according to their improvement. As Fig. 5 shows, we could observe, as an example, that regarding question 1, Profile 1 had an average of 2.6 over 5 at the beginning of the workshop for the first question, and 4.6 over 5 at the end of this. Once the percentage of improvement it is calculated, it is observed that students have increased their knowledge about 77% from the initial situation ((4.6–2.6)/2.6) In this case, the percentages are useful to understand the effect of the workshop on designers from different profiles. The workshop was useful for all participants since, regardless of the degree they

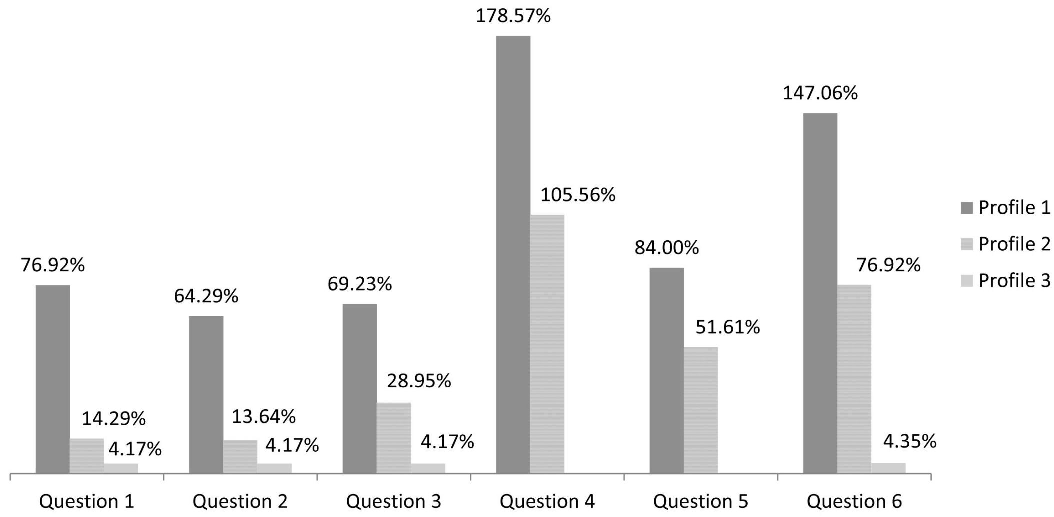


Fig. 5. Percentage of improvement of each profile after the workshop (from the starting situation).

were studying, it meant an increase in their knowledge and level of information.

Students from Profile 1 and Profile 2 learned more than those with Profile 3, showing higher percentages of improvement from the initial situation in every single question. Question 4 and question 6 are the most useful questions to these profiles, followed by question 5. Some of the questions, including those related to legislation (4 and 5), were very useful to both of them and so most of the students became aware of the WEEE Directive. This is currently most evident in the case of students from profile 1, since according to results shown in Fig. 4, their knowledge in this field increased significantly from its knowledge at the beginning of the workshop. On the other hand, this question did not lead to any variation in the knowledge of Profile 3.

In question 3, concerning the inclusion of end-of-life recommendations, students were more willing to integrate them into their projects. In this case, it is interpreted that the more environmental information the designer has, the more willing he or she will be to integrate environmental considerations into the product. From our experience, the integration of these environmental recommendations in the design and production of electrical and electronic equipment notably improves the re-use, dismantling and recovery of WEEE as set out in Directive 2012/19/EU. If the professional designer is unaware of the latest legal requirements, (Waste Electronic and Electrical Equipment Directive), then non-compliance may occur when new products are introduced [56].

Finally, with regard to question 6 about how an e-waste recycling plant works, students do not have access to specific information about the recycling of waste electrical and electronic equipment, since this is not dealt with in any specialized subjects in their bachelor's or the master's degree. Partnerships between universities, production companies and private recycling plants could improve the development and integration of sustainability in the product design.

After collecting the assessments and opinions of the participants in order to accomplish the third objective, it was observed that the workshop had met the students' expectations. Based on results from question 7 evaluated on a scale of 1–5, an average of 4.5 was obtained, which means a level of satisfaction of 90.4%. In addition, the workshop was useful for all participants, since it enabled them to increase their knowledge in this field, regardless of the degree they belonged to. These results show that the designers' environmental knowledge is strongly related with the intensity of their environmental education. However, this is also due to the intrinsic motivation of the student [22], since the 25 participants attended the workshop voluntarily.

5. Discussion

From our pilot project, we realized that there is a need of environmental education in the field of incorporating the end-of-life requirements into the design process during the learning process of students from degrees related to engineering product design. It is therefore necessary to encourage the inclusion of subjects or practical assignments that enable future designers to work with the end-of-life of these products in a realistic way. From our results we can state that the more information the designer has, the better environmental performance could be incorporated into his or her design. In this sense, it can be interpreted that fostering environmental education in future designers does indeed help further the ecodesign of electrical and electronic products. So, as a consequence of this experience, authors recommend to integrate workshops similar to the described in this paper in subjects related to conceptual product design (commonly included in any engineering product design degree) as a tool to introduce sustainability concepts within engineering design curricula.

In addition, this project stimulated students to redesign electronic toys, by encouraging them to understand the importance of considering their end-of-life for preserving the environment. The information obtained from the questionnaires answered after the workshop by each participant shows that a demand for this type of activities exists, since students found the workshop interesting and necessary as a part of their training. Although the integration of environmental education at university—and especially in degree courses related to industrial design—is essential to develop sustainable products, we also consider that partnerships between universities, toy companies and recycling plants could lead to better development of products by creating an enriching flow of information among all of them. This is in line with Hansen and Lehmann [57], who considered that promoting the introduction of problem-oriented and project-based learning in even more universities could help facilitate more active and productive partnerships between universities and other groups/organizations in society.

From the analysis of our results, we agree with Boehnert [32]: designers and educators have a unique role to play in the creation of a sustainable future. Although better integration of environmental education in university curricula is needed, there are more barriers to be overcome within the context of ecodesign. As stated by Boks [58], the lack of ecodesign implementation is still common in companies. Even though some companies are committed to sustainability through their products and despite the fact that the Directive 2012/19/EU [1] encourages cooperation between producers and recyclers to promote the design and production of products by facilitating their disassembly and reuse, electrical and electronic equipment is becoming increasingly more complex. Products such as smartphones have changed their material content and now include more critical metals and others that were not used before [59]. Even if this study shows that students are willing to integrate environmental requirements into their designs, it is also clear that most of them will have no incentive to proceed with them forever, since it is a business reality that sustainability usually plays a minor role in most industries [42]. With this approach, the focus should be on the barriers that designers face in designing for end-of-life and their inability to alter the current system.

On the other hand, the implications on design education should be studied more extensively. As an example, further research can be undertaken to investigate innovation strategies such as the Product-Service System (PSS), which shifts the business focus from designing and selling physical products to selling a system of products and services which fulfil specific client demands [60].

Finally, the relevance of designers into scientific research was observed since they have the capability of prototyping for quick testing of ideas and visualizing scenarios of use, according to the content of the workshop. [61]. In line with Driver and Peralta [25], it is important to integrate designers earlier in the scientific research process since they can challenge the research direction and support scientist in demonstrating, communicating and exploring potential future applications.

Although more rigorous enquiry would be needed in this study, since the results and conclusions of this paper focused on integrating end-of-life recommendations into the design of electrical and electronic toys that came from a specific workshop held at one university in Spain, this kind of experiences could be used to show academics that far more work still needs to be done in order to educate the next generation of designers [62]. In addition, this case study, together with others [40], could also help to define general ecodesign measures for the electrical/electronic toy sector.

6. Conclusions

Our specific workshop was intended mainly for students of bachelor's and master's degrees related to Industrial Design Engineering. This was attended by 25 participants from different design profiles. The aim objective was to investigate how theoretical and practical knowledge about end-of-life of WEEE could encourage more responsible professional practices in the design of electrical and electronic devices. According to our results, it could be observed that all the students agreed with the integration of design recommendations into their projects after dissembling the electrical and electronic toy. 57% of those which were selected were EOL recommendations. The most selected recommendations were "reducing the number of screws" or "avoiding combinations of incompatible plastics". Designers realized that electrical and electronic toys are not usually manufactured with their disassembly and potential reuse in mind.

With reference to the questionnaire after the workshop, results show that this was very useful for students, who improved their knowledge in each content of this subject. Students from Profile 3, showed higher percentages of improvement from the initial situation in every single question that those form Profile 2 and Profile 3.The questions related to legislation (4 and 5), were very useful since most of the students became aware of the WEEE Directive.

We can state that in this specific case, environmental education does have an influence on the design of electrical and electronic equipment, with products being developed with improved environmental performance and greater potential for reuse or recycling. Therefore, further actions are required to enhance students' awareness of these environmental issues in the context of WEEE.

Acknowledgments—The authors wish to thank all students who participate in the workshop for their contribution to the research. This work was supported by the Ministerio de Economia y Competitividad, Programa Estatal de Investigación, Desarrollo e Innovación Orientada a los Retos de la Sociedad (Project DPI2013-40815-R).

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