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Shaping the Conscious Behaviors of Product Designers in the Early Stages of Projects: Promoting Correct Material Selection and Green Self-Identity through a New Conceptual Model

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Abstract: Material selection for product design is a complex task. Thus, one of the objectives of this work is to analyze and understand and to promote the importance of material selection to conceive quality products with the help of designers that promote green self-identity in the early stage of new product conception. A questionnaire was sent to professional designers and engineers. Thirty-eight responses were validated, which represented the sample for this study. The aspects that influence the complex material selection process and the final quality of the products through the design and production process are presented. Taking into consideration the responses from product designers who work in the market, as well as some engineers and students who are graduating in product design, a new approach for material selection was developed. Based on a collection of main ideas from the traditional and non-traditional material selection methods, seeking to group the maximum requirements of both methods, and inspired by the "canvas" model on the basic modular methodology, a new model for new product projects is presented. Our study focuses on material selection, since this aspect is one of the most relevant steps in the early stage of the prototyping phase of new products, with a view to reducing CO_2 from the air in the atmosphere that we all breathe. The classification of materials is complex due to the diversity of available options. The novelty of this model is that all the properties of a newly designed product, such as technical, aesthetic, productive, and environmental properties, are grouped in the model, which serves as an innovative support. Thus, designers have a tool at their disposal that can help them to select the best materials for the products they design. The results of this study contribute to the field of material selection, to the quality and design of new products, and to promoting green self-identity of designers in the initial phase of product design. Consequently, all consumers in search of a sustainable planet will profit from this study.

Keywords: product design; green self-identity; environmentally friendly products; materials selection; material properties; databases; product quality

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1. Introduction

The development of a new product usually starts with an idea, which is followed by a whole sequence of processes that give rise to an invention. To protect the product from possible copies, it is normal to register a patent. When a new product is created, it is placed on the market. If it has acceptance by potential customers, this makes innovation happen [1]. Later, new improved versions of the product appear in the market. We call this process technological development [2], as new versions of a developed product appear on the market. During the product development process, material selection is of fundamental importance,

on the one hand, to avoid possible accidents, and on the other hand, to prolong the product life cycle, thus protecting the environment [3], guaranteeing its quality, and therefore, its effective performance [4]. Creating and developing new products through technological developments has become a crucial survival factor for companies. All companies seek to create wealth for the company and for the country where they operate, in ever-shorter time periods. Therefore, product development times tend to become shorter, prices tend to go down, and product quality goes up. Currently, this is a significant business challenge for companies [5], which must be carried out by engineers, designers, and business managers.

Invention is often born out of a need, or just the desire to improve something. This indication is the driving force for the development of society [6]. For this, highly qualified professionals are needed, namely design engineers, who need to select materials capable of specifying the quality of the product. In addition, they must take into consideration environmental benefits, by selecting environmentally friendly materials, as well as the possibility of reusing materials, always considering sustainability, and thus promoting designers' green self-identity [7]. Designers of products, when selecting materials, must take into consideration their properties, shapes, and densities, as well as surface finishes [8] that influence consumer choice, and therefore the final value of the product [9].

To materialize their products, engineers and designers use the most diverse materials, such as metals, ceramics, glass, wood, plastics, and composites [10]. In recent years, the use of smart materials has increased. Smart materials have been conceived to have more properties that can be changed in a controlled situation by some external stimuli, among which we highlight temperature, electrical field, pH, magnetic field, stress, moisture, etc. [11]. Technicians have at their disposal all the possible information about these properties and characteristics of materials, where the construction industry, among others, is one of the most energy consuming sections of the economies of all countries [12]. To select materials for their projects, engineers and designers use the most diverse technical manuals, magazines, computer programs, etc. Although the problems related to material selection are minimized, we know that problems persist due to gaps that exist in the selection methods that are available. Therefore, there is a need to overcome or at least minimize these gaps. For this, additional information is required.

Most of the time, the manuals that support various technicians are developed by engineering specialists. The technical language used by engineers in these manuals is not well interpreted by designers who come from the arts, but who shape the product. Designers who come from the arts and often give the aesthetic form to a product have difficulty understanding all the concepts and characteristics of the materials that are applied to products. The mechanical properties of materials should be introduced in the early stages, and it is important that designers learn the fundamentals of graphic data, as presented in the CES program [13] for material selection, designed and developed by Professor Mike Ashby [14], with assistance from his collaborators at the University of Cambridge. This program validates very important positive results. However, it adds more value to the engineering area of the product than, properly, to the aesthetic way in which the product was conceived.

In this study, interviews were conducted, and a questionnaire was sent to product designers and engineers who work in the current market and also to some product design students, with the aim of surveying the difficulties they encountered in selecting the respective materials and the way they overcame their difficulties, according to Section 3 of this work.

The above-mentioned gaps in the research led us to identify the following research questions (RQ):

- RQ1 As a product designer or an engineer, do you need to use material selection tools as well as methodologies in your daily work?
- RQ2 What are the main criteria for selecting materials that you use in your daily life? What tools and methodologies do you use?

- RQ3 What are the main difficulties you experience in the creative process phase? Do you have any suggestions for improvement?

In addition to materials and their respective selection, other aspects are relevant in the conceptual design linked with this matters, such as functional product requirements, aesthetic requirements, improvement suggestions, innovations, new production technologies of, emotions provided by materials, product life cycle, quality assurance testing, and market testing.

A literature review of the main material selection methods is presented in Section 2; the materials and methods are presented in Section 3; in Section 4, we present the main results, namely, a critical analysis of some educational materials as well as a new wider and more comprehensive model for material selection; and in the final section of this work, we present the discussion, as well as the main conclusions.

2. Literature Review

With the advance of industrialization, it has become necessary to search for initiatives to minimize the negative impacts generated by humans and their way of life on the environment, such as pollution in large urban centers, mass consumption, waste generation, and the disorderly extraction of non-renewable natural resources. In the binomial "product design and materials", multiple approaches aimed at this context have been observed, with an emphasis on correct material selection. A new product project can be considered in several contexts. First, it can mean designing with new materials that have unique combinations due to their properties. Secondly, design can involve selecting a new material that has a better combination of characteristics for a specific application [2,8,11].

To implement product innovation in a conscious and sustainable way, the environmental impact of products needs to be taken into consideration in the early stages of design. A product life cycle perspective that is based on correct material selection in the design process can guide the implementation of important eco-design measures. Product design is one of the most important factors associated with the introduction of a circular economy model. In this discipline, the decisions made influence the entire life cycle of a product, i.e., from obtain the raw material to the product's end of life. Product engineering uses resources, both technical and material, to create products. Product design engineering is based on, among other things, the use of material and technical resources to create products. Introducing circularity into the product design process is not without its difficulties [15]. Engineers and designers are professionals who, in their daily lives, are familiar with solving problems for the benefit of humanity. They are looking for the easiest, fastest, and most economical ways to use materials and the forces of nature to overcome the most difficult challenges. It has been like this over the centuries until today. These professionals have been at the forefront of the progress of human civilization. A circular economy comprises several strategies to enhance the sustainability of products. However, most of the research in this area has focused on recycling, recovering, and final disposal [16].

Creativity strongly affects the design process and the innovativeness of the related outcomes. The literature shows the usefulness of stimulation as a means to enhance creativity beginning in the early design phases, which is beneficial to the whole product development process [17]. It is necessary to integrate environmental aspects during the early stages of the design of eco-innovation and eco-ideation processes. In addition, it has been observed, that concept evaluation metrics do not exist that measure the dimensions of creativity, such as the novelty, utility, or technical feasibility of a process along with its environmental indicators; hence, current metrics do not enable global evaluations [18]. For this, it is necessary to select good materials so that the products they conceive/design are quality products [19,20] that are environmentally friendly.

Therefore, materials play a very critical role in the entire manufacturing process. The existence of various ways of selecting materials is a sign of the importance of this issue. However, proper material selection is a very important and a challenging task for many applications in product design [21]. There are over one hundred thousand different

materials in our world, and several factors must be taken into consideration to evaluate alternative materials [2] aimed at sustainability [22–24].

The first step in the material selection process is to specify a product's performance requirements, which should be related to the material's key properties [2]. Processing requirements are important, but they are of second order [25], because one of the most important issues in material selection is the properties of the selected materials, with some being more important than others. For example, the mechanical properties of a material, namely mechanical resistance (strength/stress), that is, the ability of a material to withstand certain stresses without breaking, is a matter of first order. There are other important mechanical properties, such as toughness, hardness, ductility, and resilience [26]. Selecting suitable materials for sustainable development is an increasingly important process [2]. Material selection, while still in the product design phase, is when a designer's green self-identity must be manifested, selecting materials compatible with sustainable development. When a designer has green self-identity, nature gains a lot from it [27]. Moreover, all the inhabitants of the planet win.

Material selection is of fundamental importance, both in the design phase of the product when it is conceived and in the development phase when the product begins to be improved, as well as during the product production phase. An incorrectly selected material can lead to premature product failure, which can mean disaster, as well as loss of revenue and reputation for the respective company. When selecting the most suitable material for a specific application in a product, the designer usually needs a solid and systematic methodology because there are several alternative options and conflicting objectives [8] and, even with a lot of practical experience and many years of service, it is not easy to decide. However, material selection is multidisciplinary, and its practice involves joint work among materials engineers, design engineers, and salespersons. However, for a student, the discipline of material selection unites the notions of material resistance with their remaining properties and the different methods of processing products [28].

In today's manufacturing environment, designers of new products have a large number of engineering materials [29,30] and manufacturing processes available for selection [28,31]. Choice decisions are difficult due to the high number of materials available, and material selection for a specific application should to be made during the design phase. Designers of new products must always take into consideration a large number of factors. Among the most important factors, we highlight the physical and mechanical properties of materials. In addition, other factors must be considered, such as corrosion resistance, thus promoting the longevity of products. Economic considerations are always important, since it is critical to design quality products at a low cost. The possibility of recycling materials must always be taken into consideration. There are very complex interrelationships among the various material selection criteria. Hence, the process of correct material selection is a challenging task, and it is also more time-consuming for designers [8,32].

With regard to effective compliance with the properties of materials, many materials are excluded during the selection process, leaving only a few materials that can be selected as likely candidates to materialize the designed objects. In order to achieve a sustainable society, design professionals must be competent and concerned with selecting materials that are more suitable for the intended purposes; the materials should be environmentally friendly, the so-called green materials. We know that material selection resources are constantly evolving, including databases, libraries of physical materials, and dedicated software programs and tools that help designers who conceive products. Material selection for product design needs to consider a broader material system, reflecting industry behaviors, stakeholders, legislation, access to knowledge, networks, among other issues [23]. Therefore, engineers and designers of new products must be aware of all possible issues and must select materials that can perform well during the useful life of products, seeking to reduce their costs in the face of the most varied situations and requests for performance [29,33]. All these needs must be considered, which makes the material selection process a difficult, multi-criteria decision-making (MCDM) problem [29]. Hence, appropriate material selec-

tion for the most diversified products presents itself as one of the most difficult tasks in the design of new products and in the improvement of existing products in several industrial applications. Improper material selection can result in damage or failure of an assembly and can significantly decrease performance [34], sometimes ending in disaster.

There are many ways to innovate, but the main approach is primarily through material selection. Let us look at the case of semiconductor material innovations. Engineers and designers must embrace this form of innovation. Therefore, at the beginning of a project, the greatest possible number of materials should be considered, which is reduced as the design process progresses. Then, options regarding function and form emerge, which reduces the number of possible materials to be selected. In the final phase, selection possibilities are reduced to a few materials and the necessary information becomes increasingly detailed [35]. Thus, models that assist in material selection, as well as the various traditional and non-traditional methods of material selection, are important tools for optimizing material selection for an important work. It is difficult to satisfy simultaneous requirements of selected materials, which, sometimes, are in conflict with each other [36], at a time when customers are very enlightened and demanding [9], when we know that green self-identity has been asserting itself among consumers [37,38]. This is a path capable of shaping green self-awareness of a designer, which also leads us, the consumers, to green self-identity.

There is no information without support; there is no information technology without monocrystalline silicon (or other materials in the future). Extremely complex and integrated objects could not exist without materials that provide appropriate performance [14]. New materials are constantly appearing and product designers must be up to date and know how to select correct materials.

Table 1 represents the main traditional methods of material selection used in different contexts, according to their own authors [10,30–32,39]. These authors address different requirements for material selection, most of which are common to all authors, such as technical properties. However, some authors are more careful and have added unique specifications, such as material availability, reliability, product life cycle, and environmental properties.

When selecting materials, product designers must consider many functional characteristics, namely technical properties, manufacturing requirements, and the economy. Product designers can also consider some intangible aspects in order to express their intentions in new product designs. A few years ago, it was reported that there was a need to integrate the intangible characteristics of materials in the selection process, namely the emotions provoked by the materials [33,40].

The material selection process represents a problem when it comes to decision making. It is necessary to reach a compromise with conflicting objectives, including cost, production, sizing, quantitative and qualitative properties, performances, availability, reliability, and environmental issues, among others.

On the one hand, we have traditional methods of material selection (Table 1) that have been developed essentially for engineers. On the other hand, we have non-traditional methods (Table 2) developed for designers, namely those professionals who often come from the arts and give products beautiful and interesting shapes, which are capable of provoking feelings of pleasure and emotions in their consumers.

Hence, product designers carry out material selection by combining functional properties with intangible aspects in order to express their intentions in their projects.

As such, there is no model that aggregates all the requirements of all authors. Hence, the first objective of this study is to analyze the contribution of different authors to the material selection process for a new product, towards sustained development and to guarantee its quality.

Table 1. Traditional material selection methods.

SN.	Author (s)	Material Selection Method	Variables Used	Main Requirements for the Method
1	Patton (1968) [10]	Patton's method	Project specifications Production specifications	Design specifications (product's dimensions, i.e., strength, hardness, corrosion) Production specifications (shaping and molding characteristics, as well as, joining of different materials) Economic specification (minimize production cost)
2	Ashby (1992) [32]	Ashby's method	Different classes of materials with different properties	This method is based on quantifiable properties and a correct comparison between different classes of materials and manufacturing processes This method also considers aesthetic attributes, i.e., the sensory properties of materials–to be important
3	Lindbeck (1995) [31]	Lindbeck's method	Main characteristics of material properties	This author established that the main factors to consider in material selection must be related to material properties such as mechanical, physical, chemical, thermal, electrical, acoustic, and optical properties
4	Budinski (1996) [30]	Budinski's method	Intrinsic properties (mechanical, physical, and chemical) Dimensional properties (size, shape, finish, and tolerances) Availability factor of materials	This author advised that the requirements for a correct material selection should be met by selecting materials in the following main categories: intrinsic properties (mechanical, physical, and chemical) and dimensional properties (size, shape, finish, and tolerances) This author was the first author to highlight the relevance of the availability factor for material selection
5	Farag (1997) [39]	Farag's method	Reliability Product life cycle Environmental properties	This method is mainly based on the performance of the component to be idealized and comparing different alternatives He was the first author to equate reliability requirements that define the probability of the useful life (product life cycle) of a material for the determined adjacent function Service conditions related to the environmental properties of the material and product design.

Table 2. Non-traditional methods of material selection.

SN.	Author (s)	Material Selection Method	Attributes	Main Requirements for the Method
1	Manzini (1986) [17]	Manzini's method	Innovation Innovative design	This author is one of the first authors to recognize that materials are very important to promote design innovation, and consequently, product innovation In his excellent book, "*The Material of Invention*", this author incorporates profound aesthetic and philosophical responses from designers in Italy, as well as the implications of designing with new materials in industrial production
2	Ashby and Johnson (2002) [33]	Ashby and Johnson's method	Eco (environmentally friendly)	The authors reinforce the importance of the aesthetic attributes of the materials for the exhaustive material selection for the product design They create new rules, providing functionality and technique to products and idealizing them with personality Added eco (environmentally friendly) attributes
3	Karana (2008) [40]	Karana's method	Sensorial and intangible properties Supply of emotions	This author has provided important information that can help designers to include elements such as sensorial and intangible properties in the material selection process According to this author, intangible properties are those characteristics that attribute other values, such as meanings, or provide emotions from its user, and these characteristics are difficult to identify, they cannot be identified with numbers, and it is difficult to perceive them by using the senses

In addition to a review of the state of the art material selection methods, the newly designed model intends to provide professionals involved in material selection with some improvements of the current methods, based on the responses from professionals in the sector, who, on a daily basis, seek answers to these problems, and to promote green self-identify through the green self-awareness of designers.

Finally, by summarizing the contributions of several authors, as well as the concerns of many product designers, inspired by the "canvas" model that aggregates the concerns of the most different stakeholders, a new business model based on the basic modular methodology for a project of a new product to market is presented. The model intends to answer the concerns of the surveyed professionals in the product design sector. Hence, it can help product designers to conceive products paying attention to all specificities, looking to reduce production and environmental problems and costs. Our study focuses on material selection, since this aspect is one of the most relevant steps in the prototyping phase of new products.

The main contribution of this study, compared with that of the existing literature, is a new model in which all phases of the design of a new product are contemplated. The model also promotes product designers' green self-identity in the early phase of the design of new products, seeking to contribute to a better and more sustainable world.

3. Materials and Methods

The gaps found throughout the literature led the authors to identify some research questions. The questionnaire was simple and consisted of the main open-ended questions presented in Table 3.

Table 3. Main questions of the questionnaire.

(1) As a product designer or an engineer, do you need to use material selection tools as well as methodologies in your daily work?
(2) What are the main criteria for selecting materials that you use in your daily life?
(3) What tools and methodologies do you use?
(4) Do you think it will be important to conceive a new methodology or new tool or a model for selecting materials that can satisfy the needs of the design engineer or the product designer?
(5) What are the main difficulties you feel in the creative process phase?
(6) Do you have any suggestions for improvement?

This questionnaire aimed to identify the tools used, as well as the difficulties encountered, by product designers in their day-to-day work. With the difficulties identified, it was intended to find solutions to overcome them. The questionnaire was put online and mailed to around 122 professional designers and engineers. Among the respondents, 38 responses were considered to be valid, thus constituting the sample of this work. The participants, aged between 18 and 60, were mostly Portuguese, and only a few participants were from other countries, working in multinational companies that do business with Portugal.

As shown in Table 4, with respect to gender, the participants were 60.52% male and 39.47% female. Product design professionals, industrial designers, and some engineers and design students were involved in this research.

Table 4. Profile of respondents.

Variables	Categories	Absolute Value	Percentage
Gender	Male	23	60.52
	Female	15	39.47
Professional Occupation	Product design student	8	21.05
	Engineer	7	18.42
	Product's designer	23	60.52

According to Kothari and Garg [41], this work can be considered to be a qualitative investigation. Therefore, this type of research is usually considered to be applied research, as it aims to generate knowledge that responds to practical problems. Hence, it seeks to solve problems that product designers face, namely when they encounter difficulties in material selection that are related to their profession. A qualitative investigation aims to interpret difficulties and find answers for solving problems in the daily lives of many professionals and does not necessarily require the use of statistical methods and techniques.

4. Results

The designers of new products must give the true importance to material selection for the development of a new product, in order to validate their choices and to design quality products that are friendly to the environment.

In this study, 72% of respondents felt the need for more information on material selection methodologies and tools. Materials are constantly evolving, and as such, it is important to update knowledge, namely through a knowledge refresher course every two years, due to the emergence of new materials, among which we highlight "high resistance composite materials". Correct material selection for a new product is indispensable in the development of a new product. The tools used by professionals who design new products help them to understand the limits to which materials can be exposed, as well as in the respective production processes. The material selection tools are important for helping to develop new products as well as for potentially improving existing products.

The main material selection criteria that the surveyed professionals responded to are shown in Figure 1. Cost, manufacturing processes, and functionality represent the three main criteria. The professionals confirm that, for products produced in mass production, cost comes first. For functionality, the purpose for which a product is intended is important. Questions related to the technical properties of materials are also very important. Respondents also gave importance to the issue of recycling, as well as the duration of a product's life cycle. It is in this type of approach that the green self-identities of designers of new products are modeled, namely, designing quality products, increasing the life cycle of the products, and taking into consideration the recycling of materials at the end of the product's life cycle. Thus, consumers who are concerned about the environment will be able to purchase new products knowing that the issue of sustainability was taken into consideration in their products' designs. This is the path forward for new product designers towards a sustainable society.

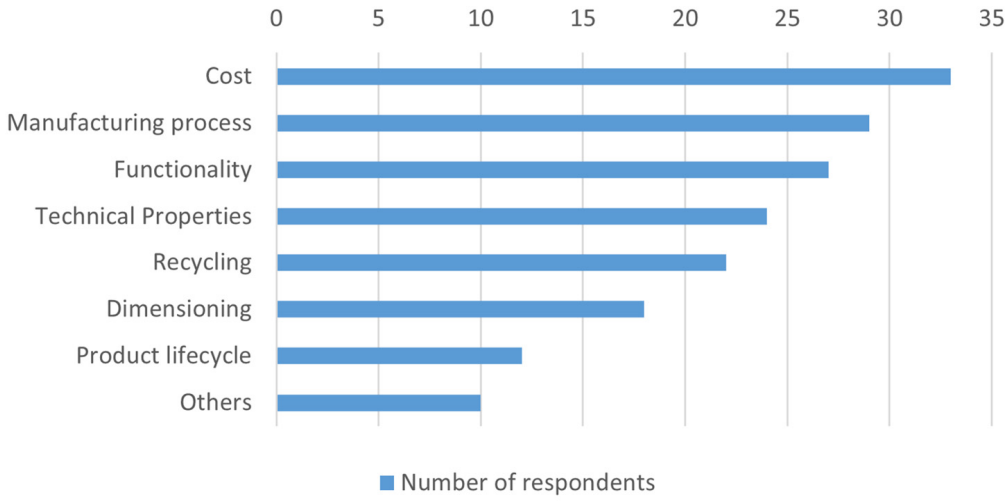

Figure 1. Material selection criteria.

We know that chances are occasional, but facts and theories are constant and must be analyzed, making the problem less complex.

With this, we try to show that the existing methods and material selection tools are not so available for those who need them. It is known that there are some gaps in the use of material selection tools by design engineers and product designers. Sometimes the existing material selection tools are not obvious to the product designer or design engineer, and they find it difficult to interpret the data. Current tools use a specific technical language, with which some designers are not very familiar, namely those with training in the arts who develop more aesthetic concepts. It is important to improve the technical language so that it can be understood by the professionals who need to use it, to use explanatory concepts that can be understood and assimilated, namely by those who have their training in the arts, and it is very important to give aesthetic form to new products or to improve existing products.

Before the age of information technology, conceiving and sizing new products was the most common way of creating new product designs. However, with the advent of computers, the Cambridge Engineering Selector (CES) program, which is a software package, has helped to answer many questions.

As shown in Figure 2, CES is one of many used by professionals, such as engineers, designers, and engineering students. They have the difficult task of correctly selecting the materials for the designs of the products they develop and which we all use.

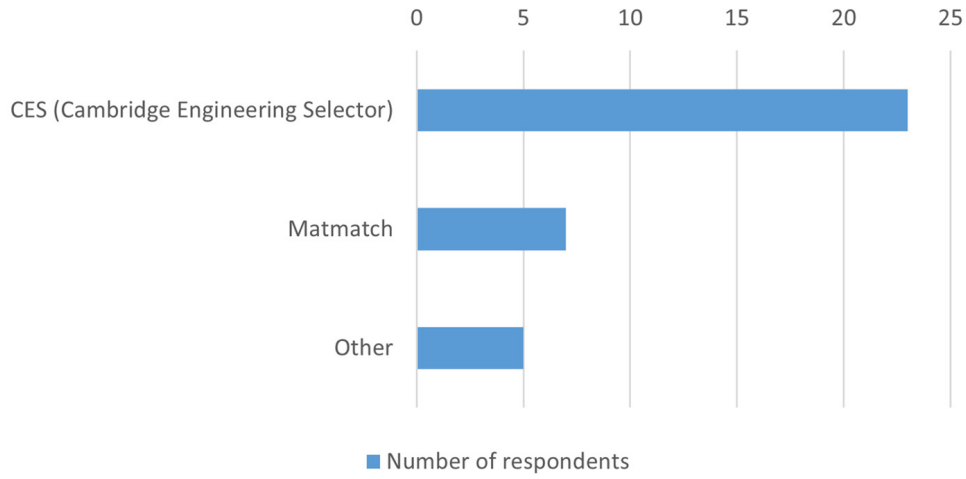

Figure 2. Most used tools in material selection for product design.

It is fundamental to understand the technical characteristics of materials in order to design quality products, thus contributing to the happiness of the user. It is also very important to verify that the material selection process is part of the complex creation process in product design. Hence, it is necessary to adopt a method or tools that help the product designer in the initial phase of a new project, or in the development of the proposal for the creative process of a new product.

According to Figure 3, Michael Ashby's methodologies are the most used by the surveyed professionals, followed by the Material Selection Activities (MSA) method.

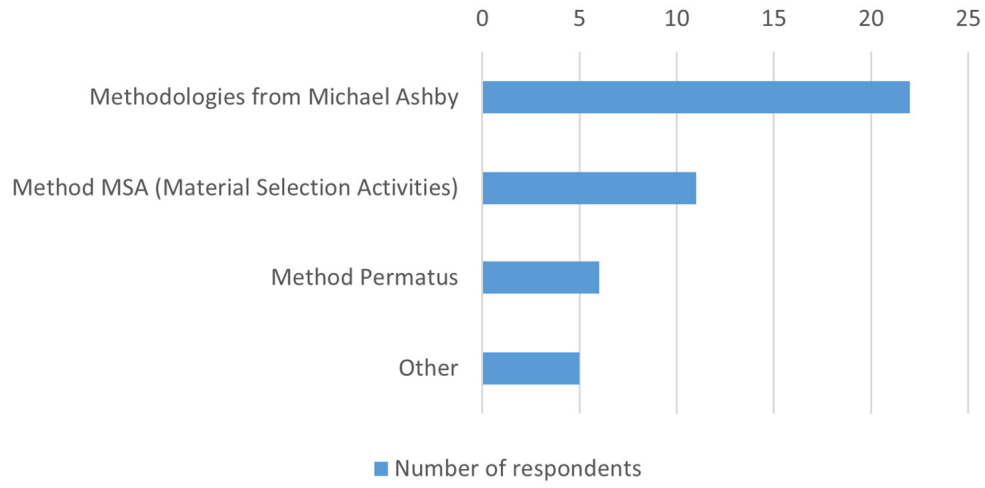

Figure 3. Methodologies used for material selection.

4.1. The New Model Based on the Basic Modular Methodology for a New Product Project

After analyzing the answers given through the questionnaire by product designers who work in the market, students who are graduating in product design, and some engineers, a new model according to the "canvas" model was developed. The main concerns of the professionals were: understanding the limits to which materials can be exposed and the respective technical properties, potential problems in the manufacturing processes and functionality, ways to reduce costs and where, the length of the product life cycle, possibilities for recycling, among others. These and other concerns of professionals helped to design the model.

The referred model, which fulfills a whole set of important requirements demanded during the material selection process, helps professionals to select materials for the products they conceive. For example, the model helps the professional to remember all the

necessary questions in each step to design a sustainable product. It could be the first step towards an interface program where each window should have all the information that the professional needs. Nevertheless, as it is just a model, it does not have all the detailed information. Hence, professionals will have to look for it. However, by consulting the required information, the designed product will comply with the rules of quality and sustainability.

The new model, shown in Figure 4, is intended to be a tool to help product designers with material selection for the development of prototypes of new products for the market. The presented model is based on the basic modular methodology for a project of new products to be implemented and developed in the industry. Application of the modular methodology, presented in Figure 4, helps product designers to find the best material selection solutions for the products they conceive.

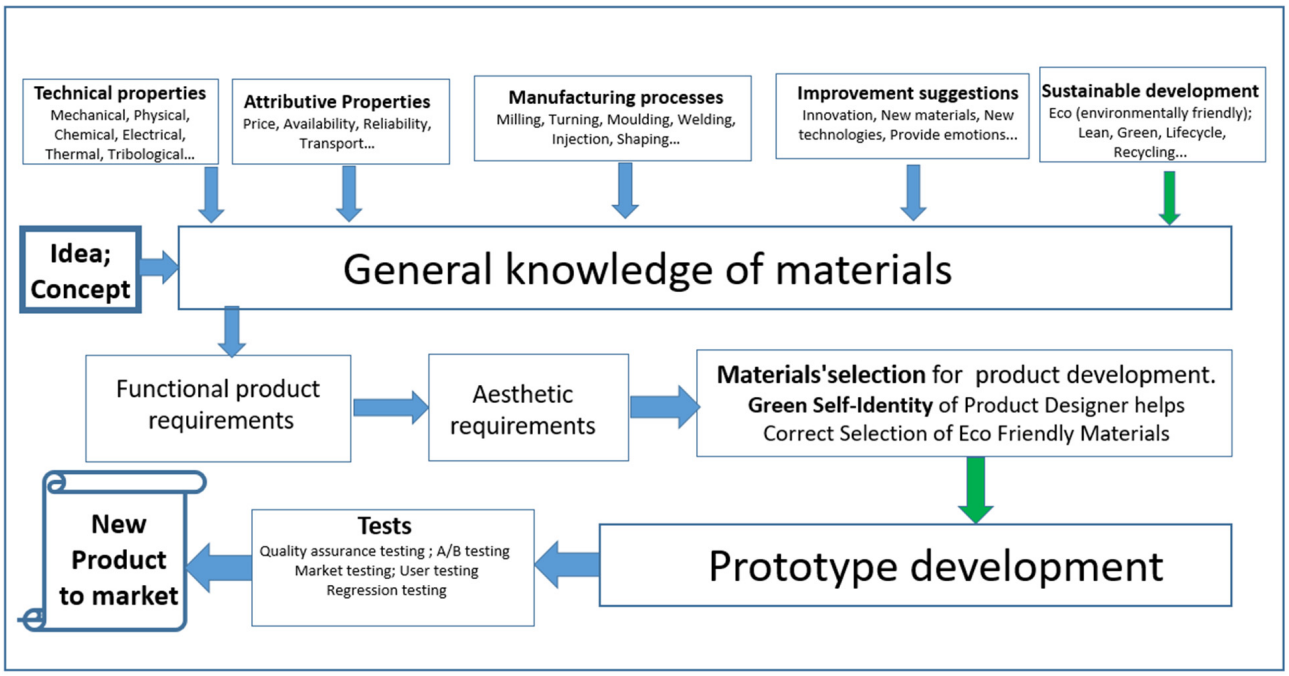

Figure 4. The model based on the basic modular methodology for a project of a new product to market, covering the main methods of material selection in the early stages of the project (source: authors of this paper).

It all starts with an idea or concept. Then, sketches are executed and the properties, namely technical properties of the materials available on the international market, are analyzed. The functional and aesthetic requirements of the new product are also analyzed. In the next phase, specific materials are selected for the development of the product, namely environmentally friendly materials, as well as the manufacturing process. The prototype is designed. Tests are carried out, and the prototype is improved and optimized. Finally, a new product is put on the market.

Regarding the survey question "state the main difficulties faced during the creative process phase", it can be concluded that material selection is a difficult issue for all the research participants, for some, due to a lack of knowledge about some of the most diverse properties of materials, and for others, due to the diverse complexity of material choices.

There are many thousands of materials, with the most diverse characteristics and properties, and the respective selection for the final product depends on the intended use of the designed product. A simple cup can be made of metal, ceramic, or even plastic, depending on its intended purpose.

4.2. The Contribution of Green Materials to Designers' Green Self-Identity towards Sustainability

If all the concerns of designers regarding material selection are addressed in the early stage of product design, such as selecting environmentally friendly materials, we can hope for a decrease in CO_2 and a cleaner planet. Nevertheless, unfortunately, this has not happened, and since 1937, according to Figure 5, CO_2 levels have increased. The planet we live on needs better eco-friendly materials and designers' green self-identity.

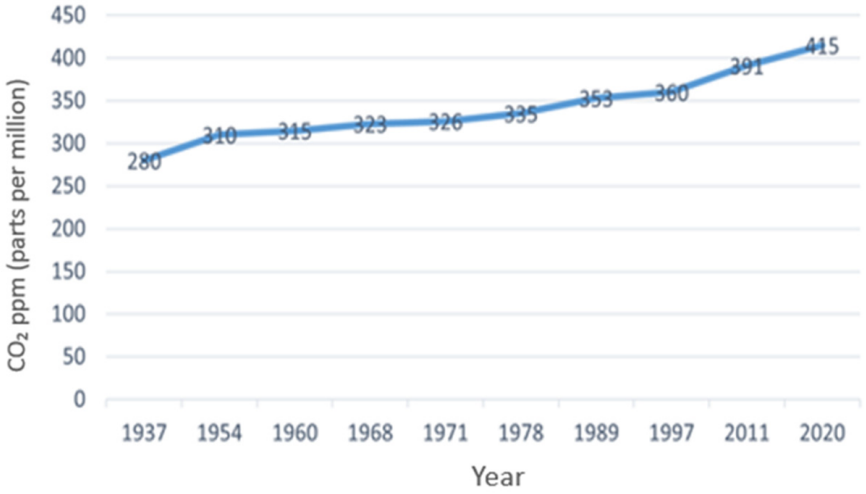

Figure 5. CO_2 ppm (parts per million) over the years. Prepared by the authors with data from David Attenborough [42].

To contribute to a better world, products that become technological innovations must be able to respond, namely to economic problems and, simultaneously, to demographic problems. In a world with more inhabitants and a constantly growing middle class, the demand for essential goods has increased, contributing to a greater carbon footprint, as shown in Figure 5, where over the years we will have increasingly polluted air with more and more parts of CO_2 in the air that we all breathe. There is no planet B. It is essential to use green, environmentally friendly materials that produce less carbon into the atmosphere towards sustainability. In manufacturing new products, economies of scale are essential for delivering goods at low cost. As we produce products by optimally using less material, as such, we will release less carbon into the atmosphere.

To implement product innovation in a conscious and sustainable way, the environmental impact of products needs attention in the early stages of design, as shown in Figure 4, thus contributing to a reduction in the ecological footprint.

5. Discussion

Of course, during the material selection process, the most diverse variables are taken into consideration. Mechanical properties are sometimes common to the family of materials. Attributive properties and manufacturing processes are also common to different materials. The cost is of great importance for all products. It is worth highlighting the importance of quality material selection for product design, as well as designers' green self-identity, who seeks to select environmentally friendly materials, towards sustainability.

5.1. Mechanical and Physical Properties

Mechanical and physical properties are sometimes common to a wide variety of materials. The model, in this study, was developed by focusing on responses to the needs of professionals who develop and materialize new products. Thus, the main materials are divided into large families according to the best existing literature. The main common properties of these materials must be characterized and presented. A new aspect of this model is that all the needs of a newly designed product, such as technical, aesthetic, production,

and environmental, are grouped in the model, which serves as an innovative support, i.e., a common analysis of all the main properties and characteristics of materials. Hence, product designers have at their disposal a range of intrinsic and extrinsic characteristics, which can help them to select the best materials for the objects they idealize, design, and materialize.

In addition to the requirement for correct material selection, it is also necessary to integrate quality concepts in the design phase of the product development process. Therefore, design errors and late changes in the product development process can be avoided, thus allowing shorter time to market, as well as cheaper and higher quality products [43,44]. Issues related to the environment are also important, seeking to reduce the ecological footprint and waste [45,46]. Finally, it must be taken into consideration that the selected material is available, and production is feasible [45–49].

5.2. Attributive Properties

Attributive properties are very important, but they are difficult to categorize due to constant changes in the market, constantly changing prices, the fact that the place of purchase is sometimes very far from the designer's workplace, and transportation that is sometimes uncertain, with unforeseen delays. Attributive properties are constantly changing and sometimes unpredictable. Each company has its own databases and its suppliers that it works with. It is not always easy to have the materials available to select and apply in the designed products. At this stage of the creative process, it should be noted that material selection that enables materialization of the product is one of the most relevant issues in the creative process. We consider that material selection is a fundamental interface link with a future product that is being designed. It is at this stage of product design that important aspects of the materials must be taken into consideration, of which, first, we highlight the technical aspects that promote good performance of a product, and then the consequential reduction in risks. All this should promote the lowest possible cost [8,50].

5.3. Aesthetic and Emotional Aspects of Product Design

It is also important to take into consideration the aesthetic aspects that promote a good vision of a product and sometimes contribute to reinforce the emotional aspects. After resolving the technical issues, priority is given to the requirements of an emotional design, which culminate in a surface design. Recently, three levels of design were considered: visceral, behavioral, and reflective [51]. Each of these levels has an important role, i.e., the visceral design is related to the immediate impact associated with the appearance of the products, the behavioral design consists of the pleasure of the use that is given to the products, and finally, the reflective design relates to meaning, recall, and satisfaction with the product.

Emotional design arises from the union between psychology and design, which seeks answers between the emotional and subjective association that exists between product design and people, leading to the understanding that emotions can be evoked in interactions with objects. Surface design is part of a specialty within design, having its own visual and technical language. Surface design is a creative and technical activity that develops both technical and subjective aspects, which adapts to different sociocultural contexts and different needs.

5.4. Manufacturing Processes for the Materialization of a New Product

To work with the different materials selected to materialize a desired product, there are manufacturing processes that are common to different materials. Every engineer, like every product designer, can also select the manufacturing processes that are considered to be essential for the realization of the project [52]. There are common manufacturing processes to work with, for example, metals and technical plastics. The selection of common manufacturing processes for different materials and for different components contributes to a reduction in the costs of the final products.

5.5. The Importance of Quality Management in Material Selection for a New Product

For a product to be competitive, it must have the best performance at the lowest cost. For this, it is very important to respect all aspects related to quality control [53]. Consumers in the global market currently have complete information, where they can verify the quality of products. When consumers have all the information related to the product they intend to purchase, they can make a more informed decision about purchasing the product they want. Hence, several studies [54–56] have demonstrated that quality management (QM) has been a widespread management approach worldwide during the last decades.

For the designer, lean thinking is also very important to identify and minimize possible waste. A lean philosophy as well as lean tools guide designers towards continuous improvements in a wide range of industrial activities, which cover areas such as planning, production, quality, maintenance, and logistics [57]. Therefore, designers of new products must have solid knowledge in the area of materials, in addition to good training, namely in the area of production, in particular with regard to product quality management, so that they can make their country's economy converge with the economy of the more developed countries [58].

5.6. Green Self-Identity in the Early Stage of Design towards Sustainability

It is important for product designers and engineers to have green self-identity to design sustainability-oriented products, namely in the early stage of project, thus helping to protect our planet. Green self-identity is necessary to implement product innovation in a conscious and sustainable way, and therefore needs to be given importance, preferably, in the initial stages of product design, when materials are selected. We must learn to value more ecologically correct materials, the so-called green materials. Consumers' green self-identity leads them to consume ecologically correct products, because these items satisfy their self-definition needs and they obtain personal satisfaction [7].

It should also establish an organization with environmental care, free of waste towards sustainability [59–61]. Therefore, sustainable management of a product's life cycle requires important improvements in the conception and product design processes, where the designer's green self-identity is very important. Achieving these improvements requires the use of important tools for improving the product, namely environmental and quality tools [62–64].

Improvements in production processes lead to fewer variations. This leads to the elimination of defects and better product quality, which is directly related to customer satisfaction [65]. Thus, product improvements reduce product production costs and increase the profit margin of the producers. The above-mentioned improvements promote more sustainable product life cycles [66–68], and, in particular, the use of computational tools can be helpful [69].

The world changes every day. One of the most significant contributions to climate change comes from the garment industry. Estimates indicate that this type of industry is responsible for about 8 percent of carbon emissions. This value is higher than that of international flights and maritime navigation, that is, all planes and ships on the planet together. The emergence of new materials, namely, the new field of nanotechnology, could significantly reduce the dependence on synthetic fibers manufactured with fossil fuels [70]. The world needs new environmentally friendly materials, and product designers are needed who assume their green self-identities at the early phase of material selection [71]. This concern has been reinforced in recent years [72–74].

6. Conclusions

This work aims, above all, to draw attention to the responsibilities of engineers or product designers when selecting the main properties of materials, namely technical properties, and consequently, when they select the final materials. In order to have an idea of the enormous importance of material selection, we highlight that incorrect material

selection can lead to disaster and, consequently, to high economic losses, as well as, in certain circumstances, to the loss of human life.

All customers hope that a designed product has a good performance and does not present weaknesses that can lead to serious risks and even failures that lead to disaster.

From the analyses carried out in the literature review, namely, traditional and non-traditional methods of material selection, as well as the answers given by professionals and students regarding the difficulties encountered in correct material selection, it is possible to answer the proposed research questions:

- RQ1 As a product designer or an engineer, do you need to use materials selection tools as well as methodologies in your daily work?

  The existing tools are very important for helping with correct material selection.

- RQ2: What are the main criteria for selecting materials that you use in your daily life? What tools and methodologies do you use?

The are several very important material selection criteria, as there are many variables, but the most important, for mass production of products, is certainly the cost. Manufacturing processes and product functionality are also very important. The technical properties are also important, namely mechanical resistance which, if well selected, avoids many disasters. There are other issues, also important, such as the possibility of recycling and the life cycle of the product. The CES (Cambridge Engineering Selector) is the most used tool as well as Michael Ashby's methodologies.

- RQ3: What are the main difficulties you experience in the creative process phase? Do you have any suggestions for improvement?

The material can condition the imagined piece, as well as it can also help in its conception. It is difficult to correlate all the characteristics of the materials with the production processes that will materialize the product. When moving to a prototype/final product development phase, all material selection issues are directly linked, and they all interfere with each other causing constraints throughout the creative process until the final product is obtained. It is difficult to determine the limits/restrictions necessary for the final choice of material. The time factor is always a problem. It is difficult to define the time for the creative process, and the market requires deadlines, which sometimes complicate the creative process because creativity does not have a defined recipe or method, it varies from project to project. As a suggestion, it would be good to design a model that covers as many variants of the creative process as possible. The issue of eco-design and sustainability need to be considered in the initial phase of the design of new products, exactly when the materials are selected.

The methodologies of material selection presented in this work, as well as the newly developed model that is based on the "canvas" modular methodology, can help designers of new products to correctly select materials, so that their products have good performances and long life cycles. Special attention should be given to environmentally friendly materials, as well as recycling.

This paper describes the context and importance of sustainability in today's world. It identifies the problem and presents the purpose of the study, as well as a new model that helps designers to select materials for the products they design. The model covers all the steps in the development of the early phase of a prototype. Designers can address this concern during the creative process. It reinforces designers' green self-identity, which is very important for the sustainability of the products. This is certainly the desire of all companies and of all consumers towards a better and cleaner world.

This study contributes to the broader field of sustainability because, if new product designers have green self-identities in the early stages of new products, they will do the right thing on every project. All designers working in this direction will be a huge contribution to sustainability.

7. Limitations of This Work and Future Research

Although this work has achieved its objectives, i.e., seeking to find answers to important questions, it has limitations. More questions and a larger sample would certainly give more consistency to our work and could help to confirm that having a green conscience or self-identity in the early phase of new product design will contribute to a better world towards sustainability.

Future research with more questions may reinforce the methodology based on the new conceptual model presented in this study. It would also be important, in future work, to test the model and to apply new technologies such as 3D printing.

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