Jul 11th, 9:00 AM

Materials Selection: from technical to emotional material properties

Maria González
Elisava Escola Superior de Disseny i Enginyeria de Barcelona

Javier Peña
Elisava Escola Superior de Disseny i Enginyeria de Barcelona

Citation

González, M.,and Peña, J.(2013) Materials Selection: from technical to emotional material properties, in Reitan, J.B., Lloyd, P., Bohemia, E., Nielsen, L.M., Digranes, I., & Lutnæs, E. (eds.), *DRS // Cumulus: Design Learning for Tomorrow*, 14-17 May, Oslo, Norway. https://doi.org/10.21606/learnxdesign.2013.059

DRS // CUMULUS 2013
2nd International Conference for Design Education Researchers
Oslo, 14–17 May 2013

Materials Selection: from technical to emotional material properties

Marta GONZÁLEZ* and Javier PEÑA
Elisava Escola Superior de Disseny i Enginyeria de Barcelona

Abstract: *Materials now have the ability to transform energy, to adapt to the environment and to mimic effects only previously possible for nature. They change their properties with external stimuli and provide different perceptions depending on environmental conditions. This dynamism then converts the materials into pure mechanism, pure machine, pure image and pure feeling. The relationship of the person who works with the material, engineers, designers, etc. is no longer so direct. This connection based on experience, on a physical and perceptive knowledge of the materials is today mainly abstract. This fact hinders material selection, as it focuses on the technical characteristics, missing their sensorial inherence. Considering this, a working methodology has been created combining the selection based on technical and sensorial properties. For the selection based on technical property, databases such as CES Selector, MatWeb, CAMPUS, etc. are used. While for the selection based on sensorial properties have been worked with Materfad, Materials Centre of Barcelona and its physical database that permits to know, touch and feel 4000 innovative materials samples. These have allowed the proposal of a convergence between both criteria and introducing the material selection in the beginning of the product design and development project and thus prevent the student from postponing the selection to the final phase.*

Keywords*: Materials Selection; Functional Materials; Sensorial Properties.*

*Corresponding author: Materials and Design Department / Elisava Escola Superior de Disseny i Enginyeria de Barcelona | Universitat Pompeu Fabra | Spain | e-mail: mgonzalez@elisava.net

Introduction

Today, the engineer/designer's relationship with the materials is no longer direct in most cases. Due to the large number of materials, the projectors' knowledge of them is generally abstract. There are a large number of materials databases that allow technical information to easily and quickly be obtained on them (Ramalhete, 2010). However, there is difficulty in interaction and direct experimentation. This makes selection difficult, as it is principally based on the technical characteristics and in many cases fails to take into account the inherent sensorial properties. Therefore students (later professionals) choose the material in the final stages of the product design and development process.

In recent decades, a new category of *functional* or *smart* materials has appeared. These are capable of transforming energy, of adapting to the environment, of changing their properties in the face of external stimuli. In addition to their passive function, these materials produce an active action like changing shape, colour, physical properties with rises in temperature, when an electric or magnetic field is applied or when the pressure is changed, etc. Some examples are shape memory materials, electro and magneto-active, photoactive and chromo-active materials (Peña, 2008). It is difficult to standardise the properties of these materials and the information the designer requires to select them and use them generally comes from experimentation, the reality of the project (Burman, 2000). This makes the selection process difficult and in many design projects, the use of functional materials does not go past the conceptual phase. Experimentation with functional materials has been performed, among others, to investigate their use in the active disassembly to aid recycling of consumer electronic products (Chiodo, 2002) or to examine the applicability of shape memory alloys in different kinds of actuators (Tammi, 2007).

In this work, we propose a singular combined teaching model from Elisava Escola Superior de Disseny i Enginyeria de Barcelona (Elisava, 2012) based on experimentation with the different structured databases to know the materials technical properties. At the same time, the sensorial properties and knowledge of the functional materials are worked on through Materfad, Materials Centre of Barcelona (matériO Barcelona) and its physical database of more than 4,000 materials (Peña, 2008), and by experimentation through laboratory practices with piezoelectric and shape memory materials (Materfad, 2012).

Digital tools for materials selection

Today there are more than 160,000 materials available. Of these, most of those we use today were developed in the last hundred years (Ashby, 2007). There are different databases, but MatWeb (MatWeb, 2012) is the one that offers most information (principally physical, mechanical, thermal, optical and electrical properties) and the largest number of materials, approximately 74,000 (Ramalhete, 2010).

An important selection tool is the CES Selector software (Cambridge Engineering Selector) developed by Ashby along with Granta Design and Cambridge University (CES Selector, 2012). This database starts with the universe of materials, subdivides into families, classes and ends in the subclasses. It allows graphs to be made of the relationships between different properties, which facilitates the elimination of materials that fail to meet the necessary requirements. It gives us information on physical, thermal, electrical, optical, durability and environmental qualities and applications of more than 3,700 materials. It also allows information to be gained on processing methods and suppliers. Other databases are CAMPUS (CAMPUS, 2012), which offers information on the plastics industry and has a database of more than 4,200 materials, and eFunda (eFunda, 2012), in which it is possibly to simply look for information on composites, metals, polymers, glasses and natural materials. Material Explorer (Material Explorer, 2012) is software that suggests a different methodology for selecting materials, not based only on an objective search, but also on experimentation and inspiration. It allows properties to be sought by smell, hearing, touch and sight.

In 1998 Material ConneXion was founded (Material ConneXion, 2012), which is a materials consultancy and a library of innovative and sustainable materials. It is intended to help companies to innovate, to create new opportunities to optimise and develop product and to use their experience to guide towards more responsible environmental solutions.

In 2001, matériO was created in Paris (matériO, 2012). It is a network devoted to materials and new technologies. It offers a digital and physical library in which materials can be selected by their visual and sensorial characteristics and their probability of innovation. It is formed by a team of experts located in different European cities (Paris, Barcelona, Prague and Anvers).

Importance of sensorial and emotional properties

A product's functionality is not the only factor that determines its consumption today, but there is increasing interest in the more intangible side of the product, such as its emotional properties (modern, feminine, sophisticated, etc.) (Karana, 2009). Between different alternative products made of different materials of similar technical properties, people may prefer one over another on the basis of the intangible characteristics of materials. The origin triggering a material's emotional properties are its technical and sensorial properties. One example is metals, which are cold and can connote precision as they seem lasting and robust. Designers can therefore use them to stress the high level of a product's engineering. The fundamental requirements of designers in the materials selection process has been established in the following order: sensorial properties (vision, touch, sound, smell and taste), intangible characteristics (emotions, associations, cultural meanings, etc.), technical properties (manufacturing processes, cost of production, etc.) and design notes (design limitations, joining, etc.) (Karana, 2008).

The existing sources for selecting materials provide useful information on the technical properties (physical, quantifiable). However, only some of them bear in mind the sensorial properties in combination with the technical, such as Material Explorer and Materfad (matériO Barcelona), for example. These properties are those which describe the interaction between the material and the user through the five senses.

The technical properties of a product's material must meet the functional requirements for a certain use and the sensorial properties must attract the user's senses, while reinforcing the materials' functional part. Therefore, designers are responsible for considering both types of properties in choosing the right material for each application. The frontier must disappear, the functional will be sensorial and the sensorial will be technical.

Objectives

In this work, we suggest starting with certain functional qualities of some materials to cause inspiration and therefore new product conceptualisation. In a certain way, the intention is to focus the material selection process on the initial need posed in the concept of the product and inspired by these new materials. The objectives of this work are:

- To suggest a teaching methodology that allows students to confront product conceptualisation synergically with the properties of the new materials.
- To work on the skill of designing and selecting both functional and structural materials bearing in mind not only their technical but also their sensorial properties.
- To ensure that students achieve the necessary experience to be able to discern between types of materials based on the function they will have in the product.

Methodology

Traditionally, the materials selection process is that presented in Figure 1.

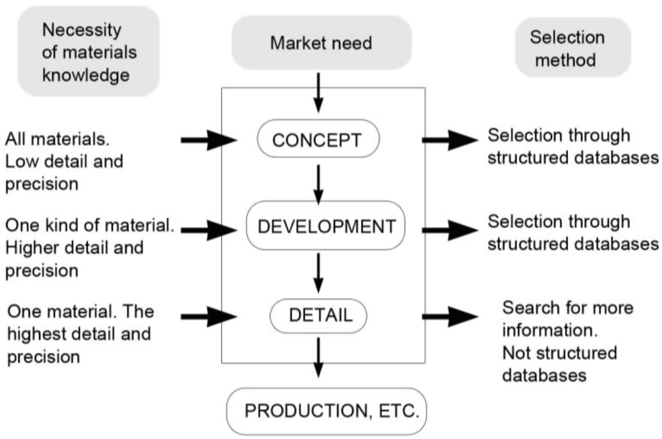


Figure 1. *Needs for materials selection in the design process.*

It starts with a new idea or a market need and commence the conceptual design phase. In this phase, knowledge is necessary of existing materials, information which can be sought in the structured databases (technical sheets, specialised selection software, etc.). The following stage is the product development phase, in which it is needed knowledge of one type, a list of candidate materials. The information will once more be sought out in the structured databases. Then comes the detailed stage, which finishes with the preparation of the product specifications sheet. In this stage, it is necessary to know the information concerning a selected material as precisely as possible. To obtain this greater information, the search is extended to the non-structured databases (webs and other information systems).

The teaching methodology has focused on three aspects:

- Digital tools for materials selection
- Physical tools for materials selection
- Experimentation with functional materials

The theory of materials has been explained and work has been done with the digital tools that students have within reach in selecting materials in product design. As a physical selection tool, a visit was paid to Materfad and here the functional materials were put into the context of the innovative materials. Finally, the students experimented in the university laboratory with functional materials (piezoelectric or shape memory) so that they might apply their characteristics to a real product.
Work was done with second year students on the Industrial Design Engineering Degree at Elisava. There follow the details of each of the aspects on which the proposed teaching methodology has focused.

Digital tools for materials selection

The working methodology consisted of performing selection exercises of the most suitable material for a certain product. We therefore defined the objectives, requirements and properties that the ideal material must have. The exercises were resolved by requirement weighting tables and/or by selection index. The selection was based on graphs (material maps), also known as Ashby maps, in which the properties of the materials are related in pairs. As digital selection tools, work was mainly done with MatWeb, eFunda, CES Selector and Materfad. The selection was made based on the technical properties using the first three. The last one was used to work on the selection based on the sensorial and emotional properties.

Physical tools for materials selection

The image of the material and the numerous references to some of its properties is not sufficient. There is an unmet need for the materials to be touched, felt, handled. This learning and experiencing of the sensorial and emotional properties was worked on in a visit to Materfad (Materfad, 2012). On the visit, the skill of the need to design for the senses was transmitted. Students did not simply look at a technical sheet or a photograph, but were rather able to experience the value of having a physical sample, feeling its weight, its texture, its temperature, hearing how it sounds, etc.

Students were able to feel the pleasant touch of polyurethane gel and experience the impact resistance of the material used in comfort applications (Figure 2a). They smelt the polymers with fragrance which contain additives that provide them with different smells (Figure 2b), which might be used, for example, in smell marketing (smell associated with a brand, packaging, etc.). They also saw the importance of smell in fabrics with aroma microcapsules. They experienced the extraordinary lightness of aerogel, which contains approximately 98% air, and its feel and high transparency, as it has a refraction index very close to that of the air, so it does not distort the images that we can see through it (Figure 2c).

Figure 2. Experimentation with the sensorial properties of materials at Materfad, Materials Centre of Barcelona.(a) Polyurethane gel (touch properties),(b) Fabric with aroma microcapsules (smell properties) and(c) Aerogel (visual properties). Photos courtesy of Materfad.

Experimentation with functional materials

Experimentation with functional materials was done with Materfad and through laboratory practice. In Materfad the students worked with materials with shape memory properties, which are deformed at a certain temperature, and when we heat them beyond a characteristic temperature, they recover their shape. The students saw samples of their applications in implantology in a cranial seal and muscular wires used as actuators in the car industry. They were shown photoluminescent gresite, which is used as an indicator on emergency exits, or in the floor of swimming pools, which charge up throughout the day and light at night (Figure 3a). They were shown thermal colour pigment applications, pigments composed of microcapsules in which the colour changes reversibly or irreversibly with temperature (Figure 3b). They were able to see the flexibility of a sheet of light emission organic diode (Figure 3c), whose potential applications include folding and roll-up screens.

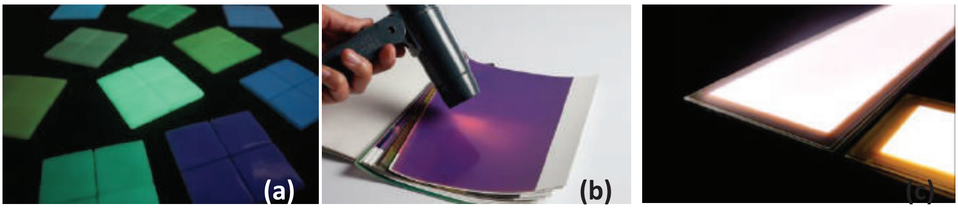


Figure 3. Experimentation with functional materials at Materfad, Materials Centre of Barcelona. (a) Photoluminescent gresite, (b) Thermo colour pigment and(c) OLED. Photos courtesy of Materfad.

In order to complete the experimentation with functional materials, laboratory practice was done with piezoelectric materials and materials with shape memory. Work was done by welding an LED to a commercial piezoelectric ceramic disc 20mm in diameter and between 3 and 30V of alternating working voltage (Figure 4a) and it was observed that when a mechanical pressure is applied to the piezoelectric part, an electric potential difference is generated, which is capable of lighting up the LED (Figure 4b and 4c). The advantage of producing electric energy from piezoelectric discs is that it is an alternative, renewable energy source which allows pupils to acquire sensitivity to environmental needs.

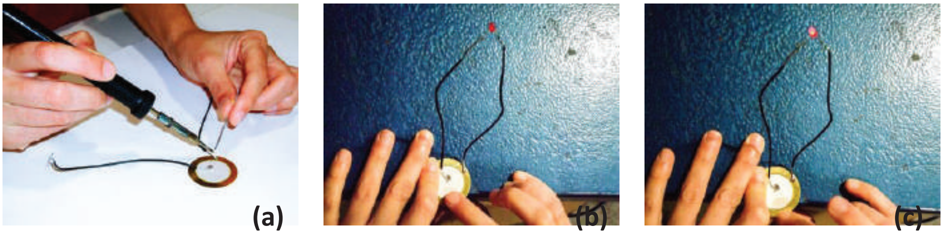


Figure 4. (a)Welding the LED to the piezoelectric material, (b) Mechanical deformation of the piezoelectric part and(c) LED lit.

In experimenting with shape memory materials, work was done with springs, muscular thread, sheet and nickel-titanium and martensitic wire. The main characteristics of the springs is that they can deform up to 30% and recover their initial shape when they are heated above a characteristic temperature of the material. The muscular thread has 3-5% of recoverable deformation. In both cases, the material does not only recover its shape, but, having recovered it, is capable of doing a job.

The wire and the martensitic sheet remember the shape that they have been given. Figure 5 illustrates the process used to give the martensitic wire the shape of a flower. First of all, the model was built with conventional steel wire. Then the martensitic wire was placed following the shape and was fixed by rolling it with the conventional wire (Figure 5a). Finally, it was placed in an oven at 500ºC for 3 minutes (Figure 5b) and was tempered in water at ambient temperature (Figure 5c). When the wire is stretched, and the ends are connected to a power source, it is heated (Ohm's law) and recovers the shape into which it was moulded.

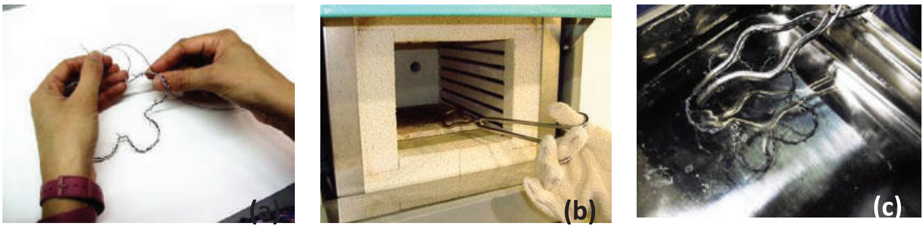


Figure 5. Experimentation with materials with shape memory. (a) Construction of the model, (b) Heat treatment and (c) Tempering.

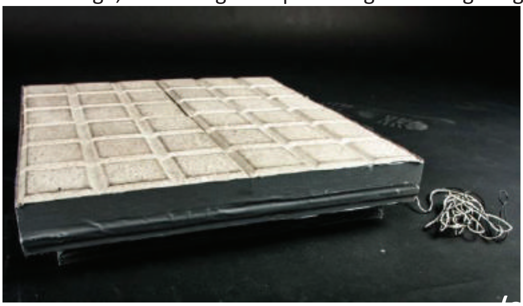
Results

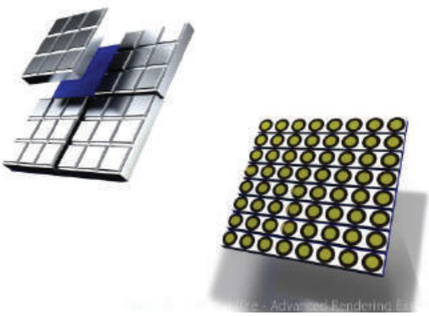
A reaction of surprise can be beneficial both for the designer and for the user. The benefit for the designer is that they can draw attention to the product (Derbaix, 2003). The benefit for the user is to be able to interact with it and to learn something new. The functional or smart materials are used very little in ordinary day-to-day products, though they have the capacity to surprise. This is because they have new, unknown characteristics, because they favour user-product interaction and cause new visual and/or tactile sensorial experiences. Their implementation may be a strategy to distinguish products on the markets (Hekkert, 2003, Lindgreen, 2003, Ludden, 2003). Another of the advantages in the use of functional materials is that the number of mechanical components in the actuators using these materials is considerably lower than the number of mechanical components of conventional electromechanical actuators (Burman, 2000).

The results of the products proposed by the students were presented in the form of a model, and five of them are shown below. Three of the products use piezoelectric materials: a tile generating electricity, a wind generator and a box with a security code. The other two use shape memory materials: car with smart ailerons and a toy dog that walks.

A. THE TILE

The tile for energy-generating floors consists of a square platform containing a layer of piezoelectric materials connected in series to a battery. The battery stores the power produced when these materials are subject to a mechanical force, which in this case will be the weight of the person (Figure 6). It is connected to an LED lighting system so that when the switch is turned on, the stored energy passes to the light emitting diodes and lights them. The students have learnt the relationship between the electrical and mechanical properties of these materials, and also the need to interact with the material so that it performs the function of generating electrical energy. Once more in this example, we see the need to experience, feel and touch the materials, and especially the functional or smart materials, to see how they transform the energy and react to cause a visual change, which might be powering an LED lighting system.





(b)

Figure 6. (a) Tile for energy generating floors and (b) Diagram of the layout of the piezoelectric disks inside.

B. THE WIND GENERATOR

The wind generator (Figure 7) generates wind energy from the movement caused by the wind when it interacts with the blades. It has piezoelectric ceramic disks connected in series to a condenser. When the wind blows, the blades of the windmill turn and deform the piezoelectric materials, which turn the mechanical energy into electricity. This energy is stored in the condenser, and a switch is turned on to light up several LEDs whenever required. The students experimented with the mechanical and electrical properties of these materials and made estimates of the energy produced by the wind generator. The wind generator may be used, for example, in isolated houses in rural areas.

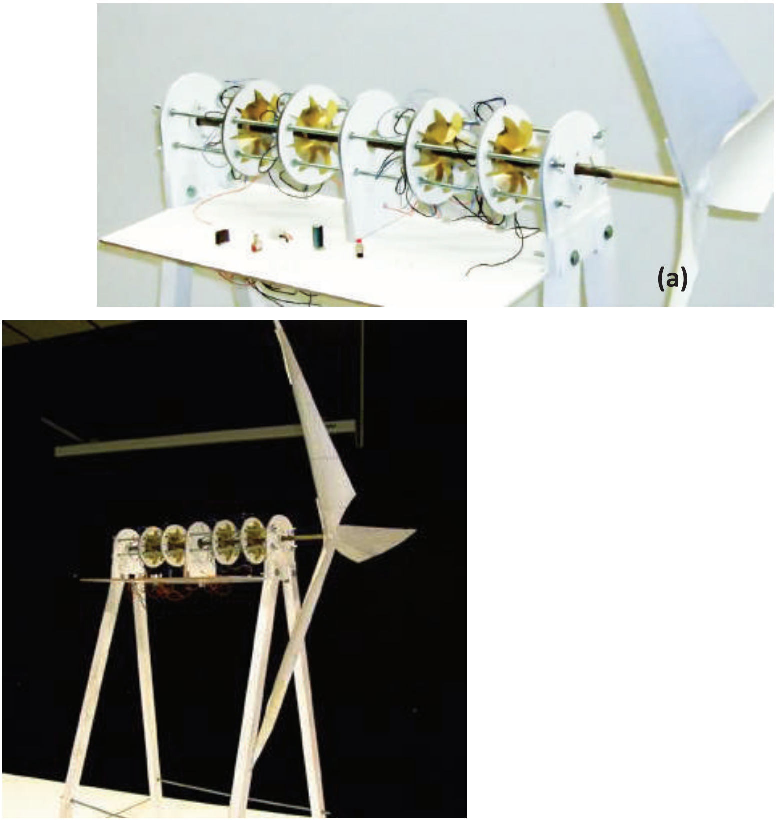
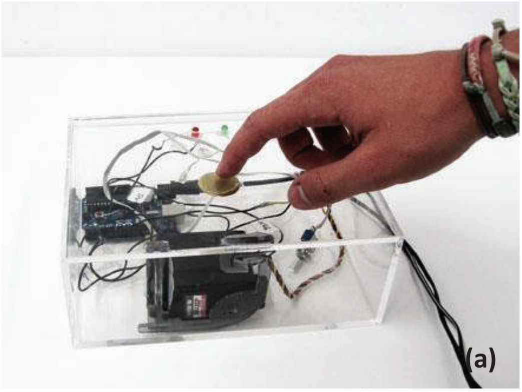
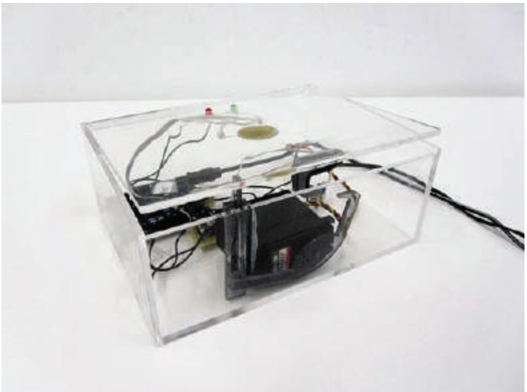


Figure 7. (a) View of the wind generator with piezoelectric materials and (b) View of the unit.

C. THE SECRET BOX

The box with a security code is activated by a tapped-in code (Figure 8). It has a piezoelectric disk that acts as a tapping sensor and is connected to an Arduino plate. Arduino is a free electronics platform based on easy-to-use software, created for artists and designers to be able to build interactive objects. The plate is programmed for the box to open when the sensor is tapped with the pulsations code that has been programmed as correct. When this happens, a green LED lights up and the box opens, whereas when it is incorrect another red light comes on. The piezoelectric material becomes a mechanism, a machine, for a mechanical stimulus applied by the user on the material becomes an electrical stimulus, and then a visual and mechanical stimulus to open the box.





(b)

Figure 8. (a) Entering the security code to open the box by tapping the piezoelectric sensor, and (b) Opening of the box.

D. THE CAR

The ailerons allow the car to take bends at high speeds, but brake the vehicle in the straights, due to the aerodynamic resistance they provide. The ideal thing is that they should do the work in the bends but should not be there on the straights. This can be achieved with moving ailerons. The vehicle's front and rear ailerons shown in the model in Figure 9 achieve the required movement thanks to a shape memory sheet which opens when the current passes through it. This movement contributes to the vehicle's aerodynamic efficiency. In this case, it is also essential to know the technical properties of the material, to experiment with it to know its reaction speed, the voltage needed to activate it, the weight it is capable of moving, etc. By experimenting with the material, students feel the emotional surprise when they see how the material changes its visual properties (its shape) and its tactile properties (the material heats up when a current is passed through it). The material becomes a machine once more, a device generating a job.

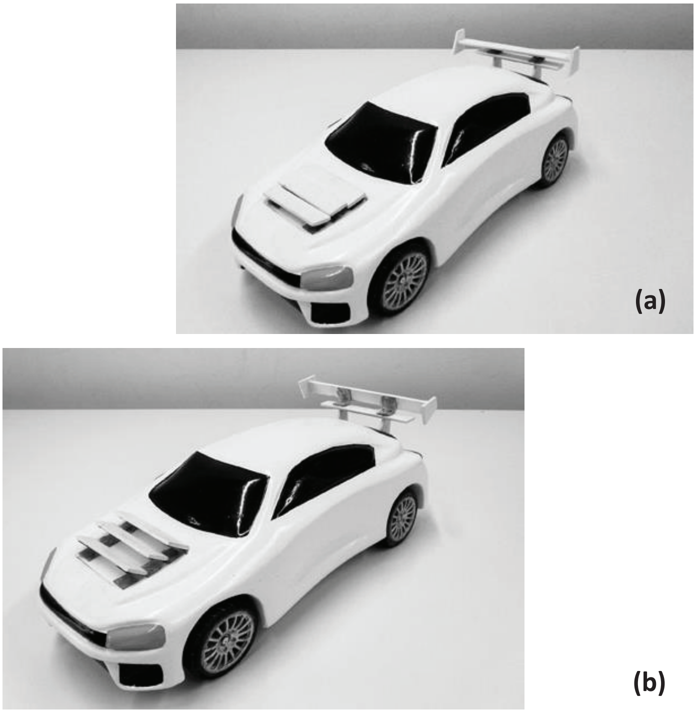


Figure 9. (a) Car with smart aileron activated by material with shape memory sheet before and (b) after activation.

E. THE TOY

The toy shown in Figure 10 is a dog that walks activated by Nitinol muscular threads. These threads have the capacity to stretch by 3-5% and to recover their initial shape when the current is passed through them. The toy's movement is activated with a glove that has metal plates at the end of the fingers. When the forefinger touches with the thumb, the current is passed and the left thread is activated, and when the thumb and middle finger touch, the right thread is activated. Students have calculated the electrical consumption and have determined that the most suitable battery for the product is a 4.5V. In this example, the material expresses the meaning of “toy”, for it acts as a machine, as a device, once more transmitting excitement and surprise.

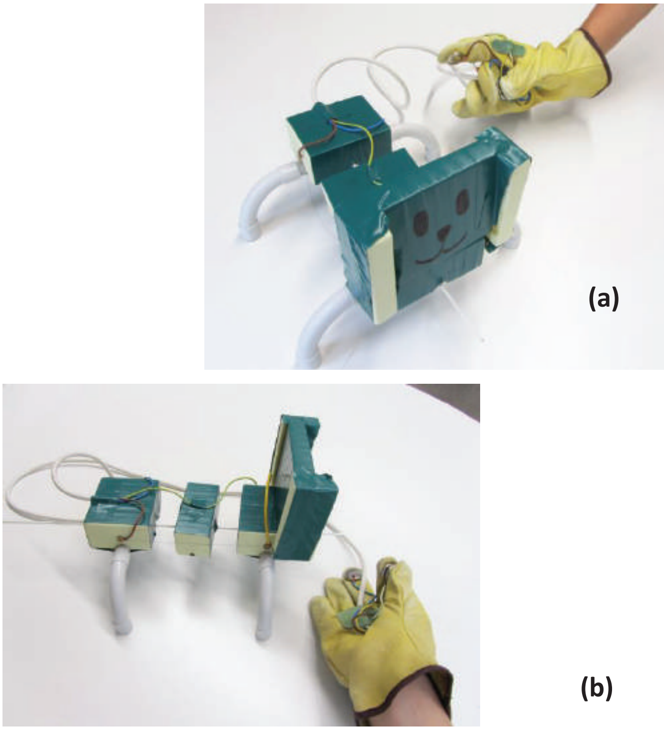


Figure 10. Toy dog walking activated by muscular thread. (a) Front view and (b) side view.

Conclusions

A teaching method has been proposed that belongs and is singular to Elisava, which has allowed students to conceptualise and develop a product from the functionality of a new material. Students have been able to physically see new functional and structural materials and have been able to work directly in the laboratory with the functional (piezoelectric and shape memory).

Using this proposed working methodology, students have achieved the necessary experience to be able to use them in their design projects.

This direct experimentation along with the digital tools for selecting materials has allowed students to acquire the skill of designing and selecting materials bearing in mind the technical, sensorial and emotional properties of the materials, and to treat both property topologies synergically in the development of the design project and the product development. To apply this model to other institutions it is recommended to experiment directly with samples or to try to create a materials library to touch and feel materials, to consider both the technical and sensorial properties in the selection process.

Finally, students have been given a methodology to enable them to use their knowledge of materials to suggest new product concepts.

Acknowledgements: *Thanks to Pau Romagosa (the tile), Edgar Pons (the secret box), Àlex Casabó, Enric Garriga (the car), Blanca Guasch, Irina Valls (the toy), Oriol Bertomeu, Alba Clemente, Joel López and Oriol Angosto (the wind generator) for the pictures of their projects. Thanks to Materfad for providing the photos from its materials library.*

References

Ashby, Michael F. and Kara Johnson. 2002. Materials and design: The art and science of material selection in product design. Oxford: Butterworth-Heinemann.

Ashby, Michael F., Hugh Shercliff and David Cebon. 2007. *Materials engineering science, processing and design.* Oxford: Butterworth-Heinemann.

Burman, Åke, Erik Møster and Per Abrahamsson. 2000. “On the Influence of Functional Materials on Engineering Design”. *Research in Engineering Design* 12: 39-47. doi:10.1007/s001630050022

CAMPUS. Computer Aided Material Preselection by Uniform Standards. [cited 16 October 2012]. Available from http://www.campusplastics.com/

CES Selector version 11.9.9., CES Edupack 2012, Copyright Granta Design Limited. [cited 4 June 2012].

Chiodo, Joseph D., N. Jones N., E.H. Billett and D.J. Harrison. 2002. “Shape memory alloy actuators for active disassembly using ‘smart’ materials of consumer electronic products”. Materials and Design 23:471–478.

Derbaix, Christian and Joelle Vanhamme. 2003. “Inducing Word-of-Mouth by Eliciting Surprise – a Pilot Investigation”. *Journal of Economic Psychology* 24(1): 99-116. doi:10.1016/s0167-4870(02)00157-5

eFunda. 2012. [cited 16 October 2012]. Available from http://www.efunda.com/

Elisava Escola Superior de Disseny i Enginyeria. [cited 10 October 2012]. Available from http://www.elisava.es

Hekkert, Piet, Dirk Snelders and Piet C.W. van Wieringen. 2003. “Most advanced, yet acceptable: Typicality and novelty as joint predictors of aesthetic preference in industrial design”. *British Journal of Psychology* 94: 111–124. doi:10.1348/000712603762842147

Karana, Elvin, Paul Hekkert and Prabhu Kandachar. 2008. “Material considerations in product design: A survey on crucial material aspects used by product designers”. *Materials and Design* 29(6): 1081-1089.

Karana, Elvin, Paul Hekkert and Prabhu Kandachar. 2009. “Meanings of materials through sensorial properties and manufacturing processes”. *Materials and Design.* doi:30: 2778–2784. doi:10.1016/j.matdes.2008.09.028

Lindgreen, Adam and Joëlle Vanhamme. 2003. “To Surprise or not Surprise Your Customers: the Use of Surprise as a Marketing Tool”. *Journal of Customer Behavior* 2(2): 219-242. doi: 10.1362/147539203322383573

Ludden, Geke D.S., Hendrik N.J. Schifferstein and Paul Hekkert. 2008. “Surprise as a Design Strategy”. *Design Issues* 24(2): 28-38.

Materfad Barcelona. Materials Centre. 2012. [cited 7 October 2012]. Available from http://es.materfad.com

Material ConneXion. [cited 10 May 2012]. Available from http://www.materialconnexion.com/PA1.asp

Material Explorer. 2012. [cited 21 September 2012]. Available from http://www.materia.nl/

matériO. 2012. [cited 13 May 2012]. Available from http://www.materio.com/

MatWeb – The Online Materials Information Resource. 2012. [cited 1 October 2012] Available from http://www.matweb.com

Pedgley, Owain. 2010. "Invigorating industrial design materials and manufacturing education". *METU Journal of Faculty of Architectur*e 27(2): 339-360. doi:10.4305/metu.jfa.2010.2.19

Peña, Javier. 2008. *Mater. Tesis*. Barcelona: FAD (Foment de les Arts i del Disseny).

Ramalhete, P.S., Senos, A.M.R, Aguiar, C. 2010. "Digital tools for material selection in product design". *Materials and Design* 31: 2275-2287. doi:10.1016/j.matdes.2009.12.013

Tammi, Kari. 2007. "Experiments on shape memory alloy actuator and practical applicability consideration". Journal of Structural Mechanics 40(1): 57-64.