Art

Art direction

Conceptualisation

Crowdfunding

Design

Design education

Design engineering

Formal design

Human factor

Interactive design

Invisible aspects

Market

Materials

Medical devices

Metadesign

Nanotechnology

New media

Open source

Perception

Product design

Product development

Production

Prototype

Sensorial research tools

Smart products

Social design

Strategy

Sustainability

Sustainable design

Synesthetic perception

Usability

Company

Engineering

Industrial design

Innovation

Project

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“Providing solutions for real implementation involves knowing how to extract the necessary information from the research field in question and the people that comprise it”

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A Look at ELISAVA’s Industrial Design Engineering

Engineering that interprets, projects, represents and builds

In this article we expose, substantiate and contextualise the most outstanding elements of the current teaching model for the Industrial Design Engineering Degree at ELISAVA. This model has been established thanks to the experience gained in 19 years of teaching industrial design engineering[1] at the school, and the ability to quickly adapt these studies to changes in the global social, economic, professional, technological and industrial environment. The analysis of these environments by the academic team is mandatory and proactive, as the professional profile of the industrial design engineer demanded by the market is understood to be sensitive to changes in society, the economy, technology and industry.

The highlights of this teaching model include the transmission to future engineers of a flexible and creative design process that allows them to take full advantage of all their skills in their professional practice, training in expression and representation in terms of product prospecting and communication, hands-on knowledge of cutting-edge technologies, the subject matter and simulation tools, and a perspective of the enterprise and business.

The body of the article focuses on the presentation and rationale of the implementation of each of these elements in the ELISAVA Industrial Design Engineering Degree. The convergence of these elements in Industrial Design Engineering projects will then be illustrated with three Final Degree Projects, which showcase professionals who have a cultural education, able to interpret the moment, to represent symbolically and, of course, design and build.

Design process for design engineering

Providing solutions for real implementation involves knowing how to extract the necessary information from the research field in question and the people that comprise it. This has led to a new design process based on industrial design engineering, en-

1 Industrial Design Technical Engineering began to be taught at ELISAVA in 1997-98.

couraging the development of a new design engineer profile equipped with broad multidisciplinary knowledge and who is expected to be agile in the use of technical and methodological tools.

Engineering definitions are varied depending on the specialisation. The definition of Design Engineer can underscore the profile of a professional who has the ability to envision the scope of the project with objectivity, equipped to generate, evaluate and execute ideas creatively [Sheppard, 2003]. The Design Engineer's premise is to design based on criteria of technical and strategic efficiency for the resolution of unresolved issues. In more detail, Clive adds that "engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems or processes whose form and function achieve clients' objectives, or users' needs while satisfying a specified set of constraints" [Clive, 2006] [Dym, 2005] [2].

The background process in Design Engineering is based on a clear and consolidated engineering design. This design comprises a process of making interactive decisions, in divergent and convergent stages, in which multidisciplinary teams of professionals work together from conceptual design to the final product. Many *workflows* for engineering design have been proposed, but most of them are similar to the workflow shown in Figure 1 [Suran, 2015] [Pahl, 2007] [Ertas, 1996]. This scheme is the starting point and work benchmark in the engineering process.

With regard to innovation-related design background, the value benchmark is taken to be the one defined by Tim Brown (founding partner of IDEO), a process called *Design Thinking* and based on the experience of IDEO-led success stories [Brown, 2008]. The greatest value in the*Design Thinking* process lies in understanding that it is a process based on innovating through design focused on the user and integrating the business strategy as a vital part of design stages. This process is described in three main areas: inspiration, ideation and implementation (Figure 2).

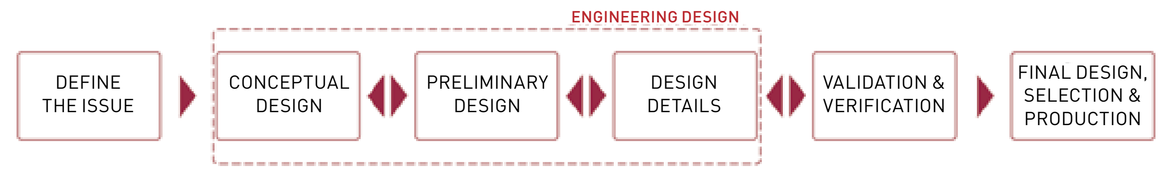
Later David Kelley (IDEO founding partner) joined by Larry Leifer and Terry Winograd founded the *d.school Hasso Plattner, Institute of Design at Stanford*. There, an academic programme was created defining in greater detail the process for *Design Thinking* (Figure 3). In parallel and jointly, the *Hasso-Plattner-Institute* founded *HPI School of Design Thinking* at the University of Potsdam, which also defined the process for the current academic model and is currently one of the most widely regarded. This case defines the Design Thinking process, outlining iterative loops between participants through six phases (Figure 4). [Steinbeck, 2011]

"The background process in Design Engineering is based on a clear and consolidated engineering design. This design comprises a process of making interactive decisions, in divergent and convergent stages"

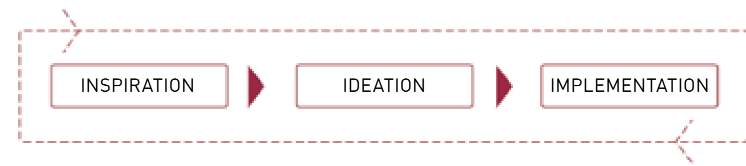
When noting the widespread implementation of these professional processes in educational models, it is considered the need to define how the academia training industrial design engineers can move forward to train engineers from a more real-life and less theoretical perspective. This would be done understanding that engineering design learning is a complex cognitive process. This learning comprises a process of divergence and convergence from a systems perspective. It is understood as an incipient project methodology that aims to standardise the engineer's and designer's project language to shape the design engineer. The designer understands the process from multiple levels of components that interact within a system or connected to other sys-

2 "Engineering design is a systematic, intelligence process in which designers generate, evaluate, and specify concepts for device, systems or processes whose form and function achieve clients objectives or users needs while satisfying a specified set of constraints".

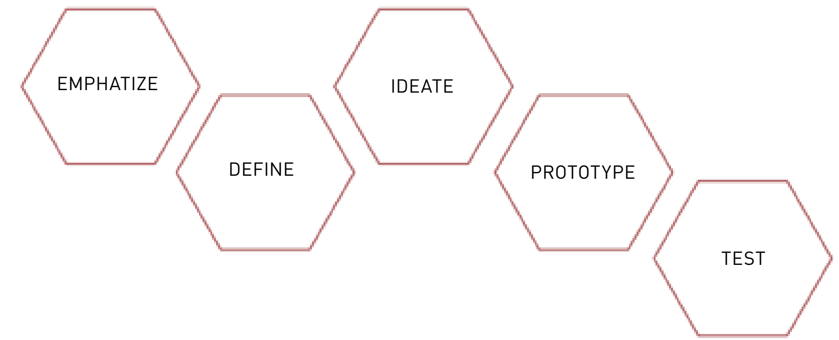
▼ Figure 1. Workflow in an engineering firm's process.



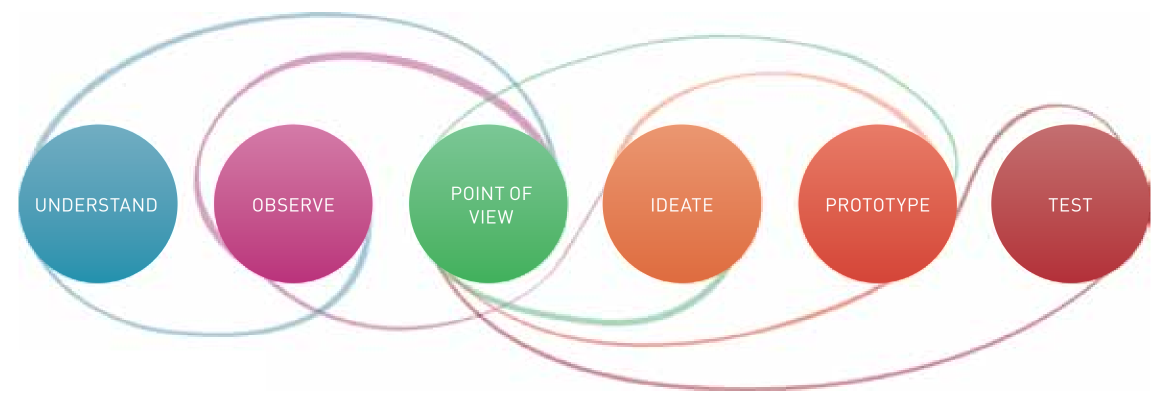
▼ Figure 2. Design Thinking process scheme, IDEO, 2008.

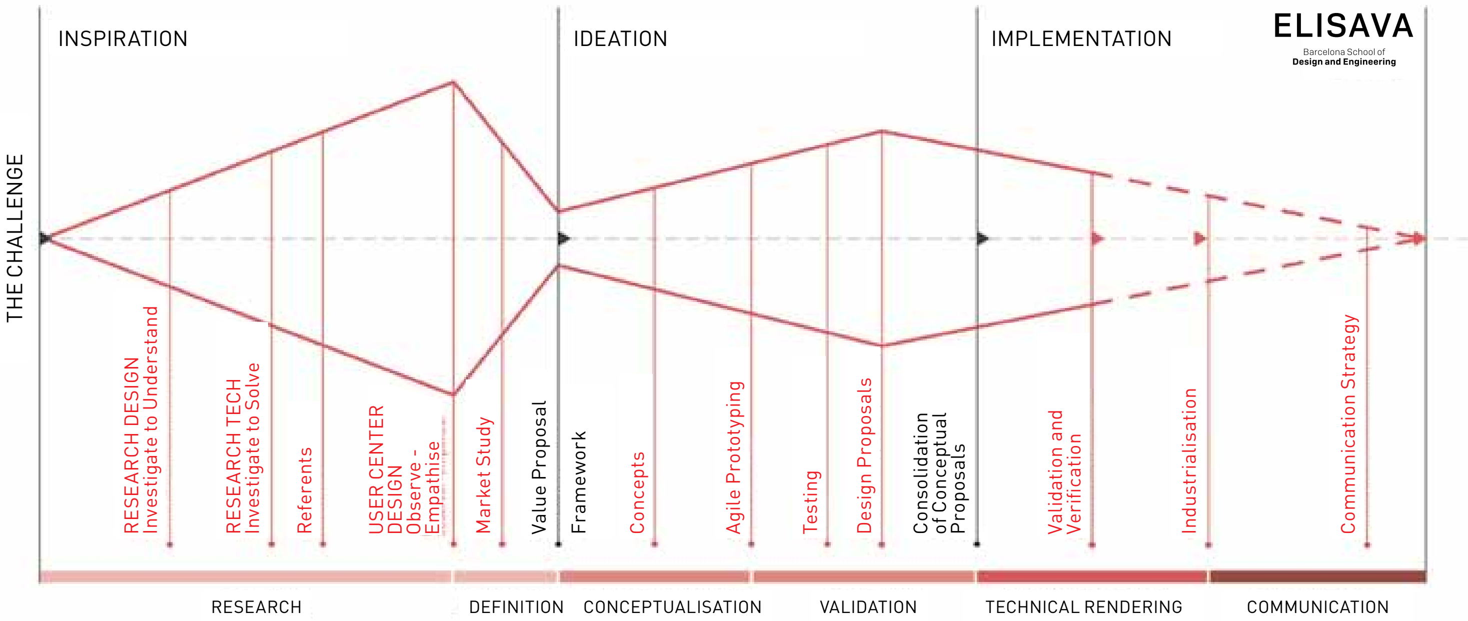


▼ Figure 3. Design Thinking process diagram, at d.school Hasso Plattner, Institute of Design at Stanford, 2009.



▼ Figure 4. Process diagram at HPI School of Design Thinking Hasso – Plattner, Potsdam University, 2009.





▲ Figure 5. Project process diagram at the ELISAVA Industrial Design Engineering.

tems. The engineer tends to solve problems and provide solutions from applied science, mainly following systemic models. [Dym, 2005]

To graphically convey the design process applied through Industrial Design Engineering at ELISAVA, it is considered important to represent it from the key project phases, the basic stages that comprise them to the point that the representation of the process through divergence and convergence of phases and stages allows an enhanced understanding of the process as a whole (Figure 5).

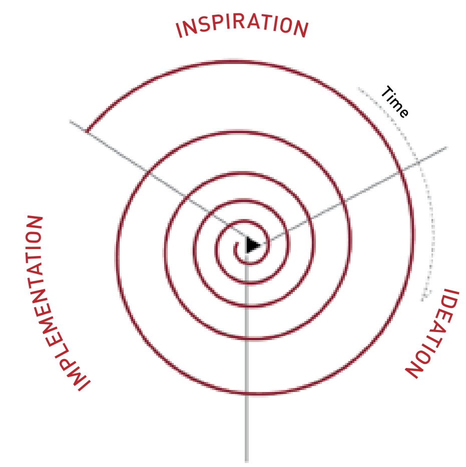
By applying this work process, it needs to be understood that it is not linear but cyclical, through phases converging towards an ultimate solution (Figure 6). It is likewise necessary to understand that the information generated in each and every stage of the process becomes a link between the parties involved which they must observe and comply with to maximise effectiveness.

The work process defined for Engineering Design that has been put forward in this article is aimed at fostering innovation. Its criterion of action is people-centred design, the pursuit of value proposition and differentiation of technical solutions by the use of cutting-edge technologies, advanced materials and parametric simulation for improving technical efficiency.

This process is defined from a professional and academic multidisciplinary team with solid knowledge of conceptualisation, creativity and product development in order to investigate, observe and understand the implications of challenges that emerge to ultimately propose added value solutions. This working model is applicable in different types of project. This will be the determining factor for the greater or lesser weight of each of the project stages.

RESEARCH FOR INSPIRATION STEMMING FROM A CHALLENGE

In the design process, scientific research is essential to have a clear understanding of the challenge in question and necessary for decision-making. In the design process, **Inspiration** is understood as the stage that seeks to understand the issues raised in a defined scope and context. The user's needs are observed and catered to, in order to discover and define the insights that drive the search for solutions to a problem or opportunity. At this point of the project the application of *Human-Centred Design*



▲ Figure 6. Timeline of dedication by phases.

ethnographic techniques [IDEO, 2015] is of vital importance, and co-creation for building empathy and understanding the product's problems and usability.

Through technological research, it is sought to define the creation possibilities and opportunities through the knowledge of technological elements and systems, as well as understanding the subject and processing it as a source of inspiration for possible ways of implementation.

Once this is understood,it is fostered the pursuit of aesthetic, formal or technical references that will help create a work framework that aligns more closely to requirements. Inspiration requires extensive market research in the requested field, analysis of design specifications, competitors and detection of market opportunities. The socio-technological and socio-cultural contexts are studied to understand the context and definition of historical benchmarks concerning the product under research.

By researching and understanding these parameters the insights can de defined. These *insights* will be the basis of the proprietary *framework* for the ideation and the creation of a value proposal commensurate to the challenge of the project in question. The project *Framework* is created by the necessary decision making, based on research, to define the design requirements prior to the first conceptual ideas.

The **value proposition** is defined after comprehensive *research* of the issues raised, understanding the user's real needs and the knowledge gained from the study of market and competitors. It puts the focus on the product or service to be provided, the problem it is meant to address, who it is aimed at and how a differentiated market proposition arises. The definition of the proposition helps when it comes to preparing the *framework* including project requirements, the basis for successfully addressing it in all its magnitude and comprehensiveness.

IDEATION FOR CONCEPTUALISING INNOVATIVE PROPOSALS

Ideation is the stage where ideas are generated, developed and tested which in turn lead to conceptual solutions. This phase of the project requires a creative and imaginative outlook. The creative process results in possible concepts that address the challenge posed. The agile prototyping stage seeks to foster ideas and allow participants to "think with their hands", using representation, communication and agile formalisation techniques. In turn, it allows effectively user-testing an idea with the aim of getting as close as possible to the final conceptual proposals. Once validated, the best ideas would be selected for development.

When the proposal begins to be defined in terms of usability, functionality, formalisation, definition of constructive and viable details, the ideation is close to implementation. At this point of the project, the Design Engineer, using graphic expression tools, will communicate form, function and usability. He or she will take into account the selection of the most appropriate industrial materials and processes to ensure the viability of the proposed concept. He or she will likewise carry out the necessary calculations to validate the technical and ergonomic performance using parametric simulation technologies, in addition to estimates of product life cycle and environmental, social and economic impact. The technical testing and consolidation of the final proposal is worked through different types of mechanical, physical prototyping and virtual simulation tests.

IMPLEMENTATION OF A DESIGN PROPOSAL GUARANTEED TO SUCCEED

In the **Implementation** step the project is executed in all technical detail to ensure proper industrialisation. Industry standards are validated and specifications are defined. The use of mechanical and structural simulation programmes consolidates the final calculations improving the variants detected in initial calculations. By using representation tools, all industrial documentation is prepared, technically explaining the assembly components and sets, assembly sequences, and industry processes and logistics. The final costs are defined, and components, logistics and resources are evaluated.

It is essential to properly prepare the material requirements planning (ERP) linked to the entire ecosystem of suppliers and project manufacturing. Each of the actors of the process required for implementation is identified to ensure that the market deployment is successful.

To ensure proper implementation, a knowledge of industrialisation is required, but a knowledge of design management will be key, as well as developing the capacity of understanding the industry and market in order to manage the design proposal and ensure that it reaches the market. It will also be necessary to be able to have an interdepartmental business vision and consider the project scope objectively. This phase of the project requires legal knowledge and an understanding of patent-related and industrial regulations as well as local and global conditions.

The implementation is concluded when implementing communication strategies that facilitate proposal understanding and value contribution to the market.

At this time the overall scope of the project undertaken becomes apparent. This is the moment to understand whether an idea has been properly designed and developed, or if it has lost value somewhere in the engineering design process. The implementation defines the design engineer's innovation capacity throughout the process, and it reveals whether he or she has been able to understand the issues raised for a solution aligned with user needs, ensuring adequate industrialisation. These validation systems make it possible to get an idea of chances of success in the market.

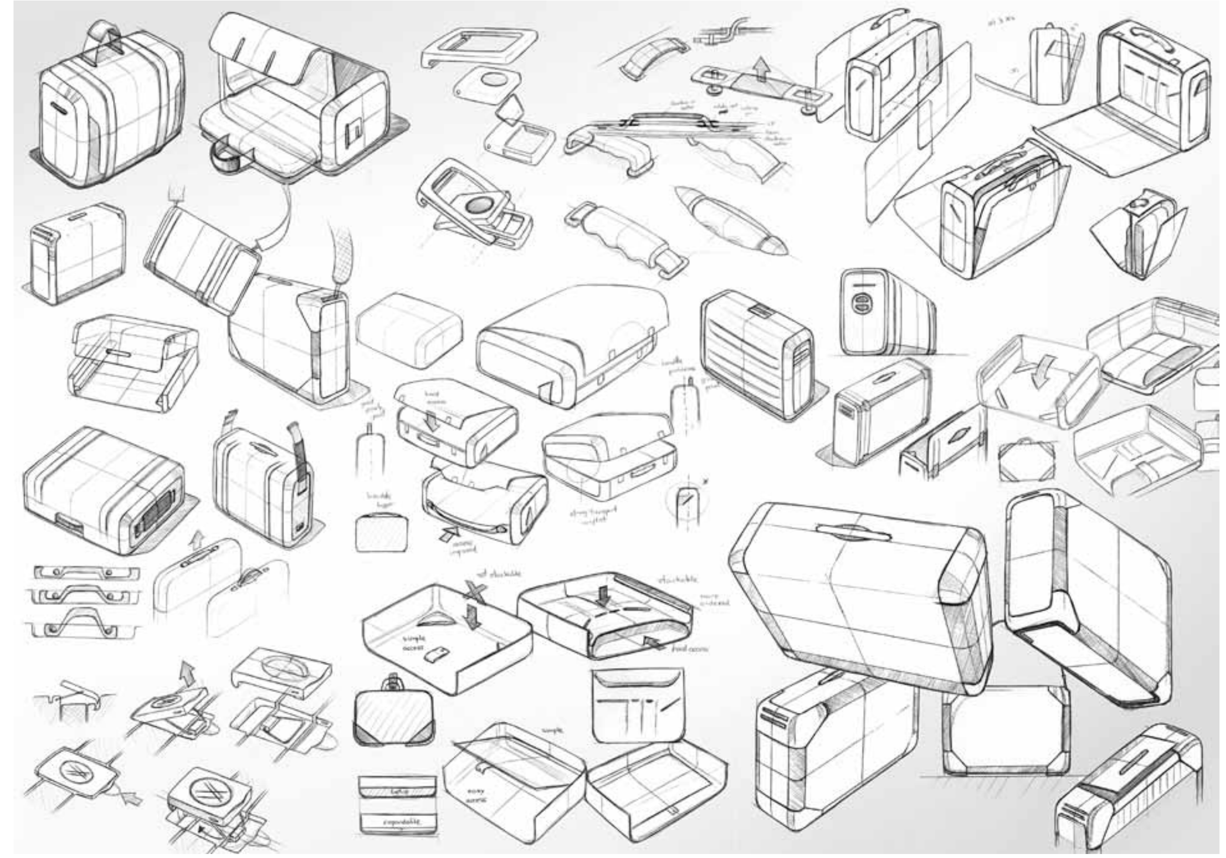
Expression and representation: exploration and communication

Training engineers in product expression and representation is basic because it supports the entire design process and product communication.

It is essential to establish future engineers' geometry knowledge and foster their observation capacity. In the Engineering Design Degree the process starts with freehand drawing, sketching products basically in a dihedral system and conical perspective (sketching technique). Learning sketching is methodical and allows students to control an effective product expression process [Eissen 2011] (Figure 7). The students then work on dihedral-system digital modelling using a CAD 2D (AutoDESK AutoCAD) tool.

By carrying out the technical project, the creation of the parametric digital 3D model of the complete product will allow students to adjust the static of its component parts, but also the product performance simulation, as it is going to be discussed in the product simulation paragraph. The digital model can almost immediately create a printed 3D model, used to verify the accuracy of the unit, make certain part adjustments, gain a realistic view of the assembly and prototyping. A fine-tuned 3D digital model can generate the technical documentation to be shared with the partners involved in the phases of product industrialisation, mainly suppliers, production line managers, quality managers and logistics managers. The 3D model also serves as a source for information that needs to be included in product user manuals, and the breakdown or disassembly processes, and reuse or recycling of components.

Currently, in most industrial sectors, the final and approved project plans are the documents on which all parties involved in product industrialisation will work. It is therefore essential that the industrial design engineer masters the technical drawing pursuant to normative codes, object representation from a geometric and metric perspective, focusing on functionality, considering the manufacturing process, technology, assembly and final disassembly.



▲ Figure 7. VIATOR project sketches.

In ELISAVA engineering, the future professional is taught 3D digital modelling in parametric CAD environments and in the mastery of product communication through normative compliant drawings, in a purely 2D CAD environment and parametric CAD 3D-2D environments. With the latter, they are first modelled in 3D to then the drawings are made based on dihedral projections automatically generated by the system.

CAD 3D environments allow rendering the digital model, a fact that allows creating different finishing options and create contexts of use, with a highly realistic appearance that can be used in product communication.

Cutting-edge technologies: Integration and Connectivity

Technological advances in the past 20 years have been key for concepts such as *Embedded Technology, Virtual Reality, Augmented Reality, Ubiquitous Computing* and so on, to be implicitly associated right now to product design. The high level of integration and cheaper technology are allowing easy incorporation into everyday products.

Technology is currently another parameter to consider when creating a product. Products from industries as extensive and diverse as automotive, sports, health, leisure and appliances are no longer understood without embedded technology.

Virtual Reality (immersive, multi-sensory systems featuring real-time response) and *Augmented Reality* (changing the perception of reality in real time), has entered our homes through leisure devices (Wii, Kinect, etc.) [Roudavski 2010], but they have been implemented in many other areas [Behringer, 1999] [Lee 2012] [Liao, 2010] [Ong 2010] and has affected all related products.

The so-called *Internet of Things* (IoT) is the face of the *Ubiquitous Computing* concept which Marc Weiser defined in 1988 [Weiser 1991]: "ubiquitous computing, or the age of calm technology when technology fades into the background of our lives." Weiser had a vision of cheap, small and robust networked devices, covering all areas of daily life, and that's what the IoT is becoming.

All this technological environment is leading to something revolutionary: increasing the functionality of products already conceived and addressing unresolved or inefficiently resolved needs. Implicitly, new paradigms of human-product interaction are emerging.

Industrial design engineers have before them this immense creative scene. It is important for them to know the possibilities offered by new hardware and software technological tools and to have the skills to work with them and get the most out of them.

Project development in *Open Source* environments—very economic or free technologies in both software and electronics featuring communities of creative practitioners sharing experiences and solutions—allows students in the Industrial Engineering Degree to gain very good training for controlling new technologies.

PROGRAMMING VIRTUAL REALITY ENVIRONMENTS

Computer science is a core subject in the curriculum for Industrial Design Engineering degrees. At the ELISAVA Engineering, the goal is to train future engineers in the design and programming of computer applications that allow them to experience the concepts of person-product interaction, interface design, UX (*UserExperience*), and usability. Virtual Reality applications are suitable to work with these concepts, but they also enable future engineers with the use of advanced technology equipment.

3 Processing and C# are high-level, complete, simple and very powerful languages that feature their respective development environments and boast a great developer community.

[Informàtica, 2014] shows a video featuring several *Virtual Reality* applications, with first-person 1:1 interaction (direct interaction of the user's whole body with digital objects) [Parés, 2013], with Artificial Vision technology support [Moute, 2011]. Applications shown have been carried out in Processing, but future engineers also work in the UNITY environment with the C#[3]programming language. This environment allows developing other interaction models (e.g. *AugmentedReality*) with which designers can use a variety of technologies such as tablets, phones, LeapMotion and KINECT.

"All this technological environment is leading to something revolutionary: increasing the functionality of products already conceived and addressing unresolved or inefficiently resolved needs. Implicitly, new paradigms of human-product interaction are emerging"

INTEGRATING TECHNOLOGY INTO THE PRODUCT

To get started integrating technology into the product, future design engineers work with Arduino, a cost-effective and simple system that allows them to create interactive products.

Arduino is based on a programmable microprocessor using a high-level language, similar to Processing, which can operate with a variety of sensors and actuators, and communication elements. This fact allows creating products that both interact with the user and products that interact with other products, i.e., developing *Internet of Things* applications.

As an example of an interactive product made using Arduino by ELISAVA Engineering students, the L8266 project [Parodi, 2015] is an object that reacts to the presence of WiFi networks, modulating its light emission.

Experiences through matter

In the physical infrastructure of today's world, it can be find a wide variety of materials largely driven by advances in technology. Technological advancement in materials and improved manufacturing technologies have been instrumental in product development and have affected the design engineer's decisions on the use of materials. Similarly, the emerging new materials, along with the increased demand to adopt a discourse of sustainability that includes an environmental vector, means that design engineers are continually challenged in their materials selection skills [Karana, 2015].

Three of the key opportunities in terms of materials experience are: be a driving force in creating sensations and emotions, achieve dynamic experiences and create personal experiences.

FROM TECHNICAL TO SENSORY PROPERTIES

The functionality of a product is not the only factor that determines consumption nowadays, but interest is growing on its more intangible side, given its emotional properties as modern, honest and sophisticated [Karana, 2009]. Materials have a morphological character—they are function, expression and structure. Some compare materials with words. Our vocabulary is richest in materials when we can express the most solutions [Alesina, 2010]. There are currently more than 160,000 different commercial materials [Ashby, 2007]. This means that the knowledge we have of them is usually abstract and based on technical data sheets. However, there is a growing interest in the intangible, emotional and meaningful side of materials [Karana, 2009].

In this process it is proposed an approach to materials that combines technical and emotional knowledge. This leads to finding new ways to experiment in industrial design, by working with materials centres such as Materfad, which boasts a physical database of more than 5,000 innovative materials [Peña, 2008]. A photo of the material and the long list of its physical properties is no longer enough. Materfad meets the real need to touch, smell, hear and feel the materials.

DYNAMIC EXPERIENCES

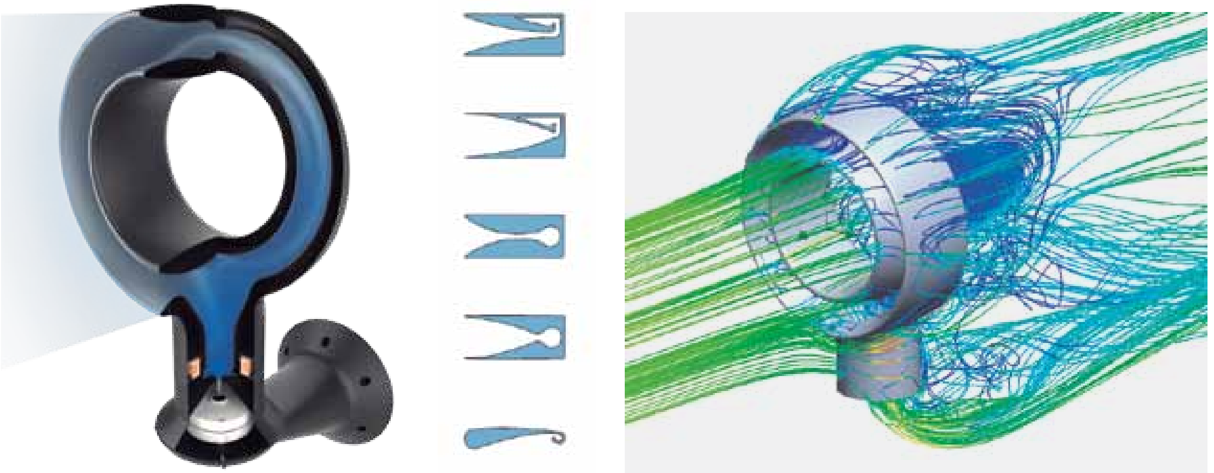
In dynamic experiences functional or intelligent materials play an important role in their ability to transform energy, adapt to the environment and/or change their properties in response to external stimuli. In addition to their passive function they provoke an active action—such as changing shape, colour, physical properties—with human intervention, for example. They stop being a static object to become something dynamic that interacts with the environment. Their unknown, unique features have great potential to surprise, to cause an exhilarating experience, if they are used in an appropriate context [Rodríguez, 2014]. The difficulty of standardising properties of functional materials is high, so the design engineer needs to experiment with them to better understand their performance and thus use them in their projects. Future professionals at ELISAVA have the opportunity to experiment with these materials through laboratory tests.

CUSTOM EXPERIENCES

In an era of abundant manufactured goods, in which people look for ways of personalising their belongings and making them unique, technological advances provide the opportunity to create personalised experiences with materials and to self-edit design products. Technological advances give the design engineer the opportunity of pushing the envelope of materials driven by the premise "I can make whatever I can imagine". This is possible thanks to additive manufacturing (manufacturing a three-dimensional object by superimposing successive layers of material).

Product Simulation

The development phase of a product is becoming more demanding in terms of the need to reduce the completion time of the final prototype, as this re-



▲ Figure 8. OXO project. Section optimisation via fluid-dynamic simulation.

duced time directly impacts project-related costs. For this reason the use of simulation tools (structural, dynamic, kinematic, ergonomic, thermal, fluid-dynamic, etc.) appears increasingly essential in the agile validation of the various product development stages.

Companies using simulation and 3D printing technologies as standard design and product engineering tools significantly reduce the costs of product technical development and this allows them to be more competitive in their environment. The transformation being experienced is an important qualitative leap, to the point that companies that do not clearly adopt these new CAx technologies (CAD/CAM/CAE)[4], will find it hard to launch competitively priced products, while jeopardising the very continuity of the company.

Future design engineers must know multiphysics analysis technologies based on the finite element method (FEM)[5], with a particular emphasis on the interpretation and evaluation of results. Structural simulation plays a key role. It allows assessing and making reliable estimates of forces, stresses and strains of a part or a product subject to profile stresses and restrictions, and static or dynamic loads. Thus, important decisions could be taken such as the design of the shape of a rib, the minimum radius of connection between surfaces, the thickness of a part and the choice of material that depend on the required safety factor.

▲ Figure 9. OXO project. Structural simulation. Calculation of tensions and strains when applying loads.

4 CAx: Computer-Aided Technologies, CAD: Computer-Aided Design, CAE: Computer-Aided Engineering, CAM: Computer-Aided Manufacturing.

5 Finit Element Method.

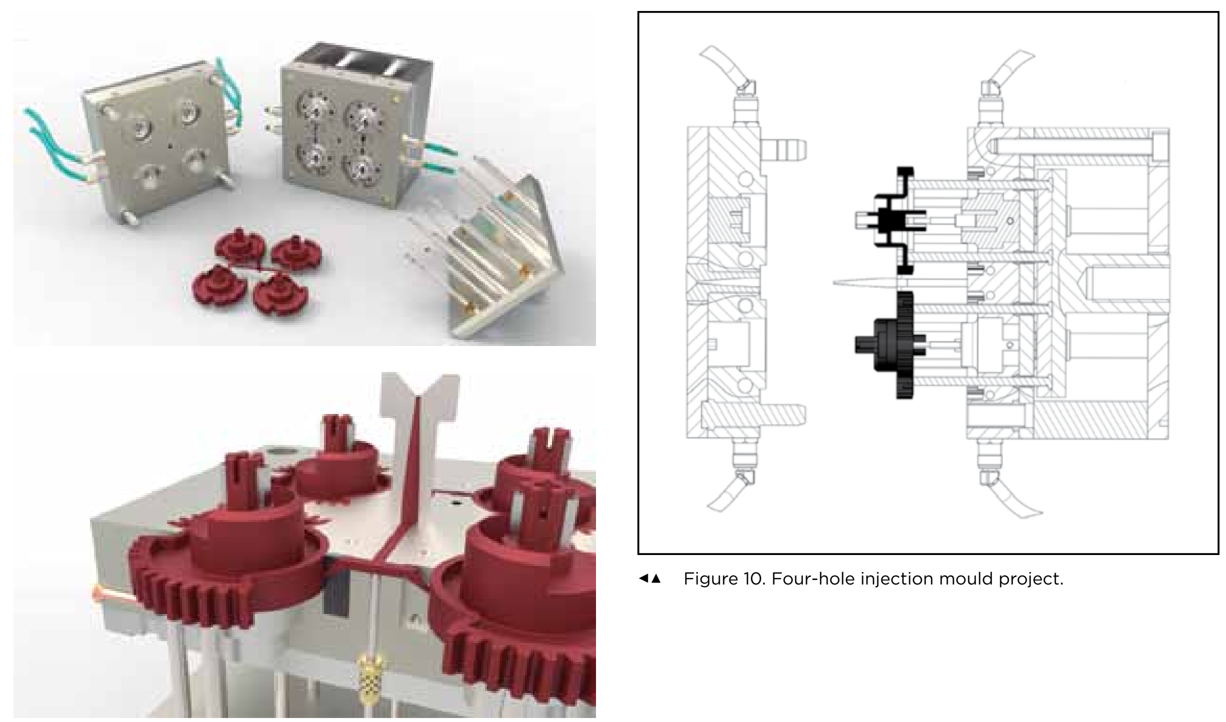
Being able to calculate the stresses occurring in a part or assembly of parts to which certain loads and profile conditions are applied, makes it possible to validate quickly if the product design is appropriate, according to its structural strength and existing strains.

An example of this methodology is provided in the OXO project, which developed a system for generating wind energy for vessels. In Figure 8, the fluid dynamic study carried can be seen, in which the simulation of the behaviour of air trajectories and the pressures and possible turbulence generated, were essential factors in deciding the air inlet section and the best way of channelling the same, in order to minimise pressure losses and ensure high performance in wind power generation.

Structural simulation allows calculating the stresses and strains withstood by the most requested parts to optimise the material and ensure safety factors appropriate to the maximum profile conditions. This requires making a proper meshing of the part or assembly to be analysed, so that the results of structural calculations are as close as possible to the actual product specs. It is also necessary that the estimate of maximum forces applied and the type of restrictions on the coupling of the various parts be performed by analysing the actual product in detail.

Likewise, the plastic material injection process simulation tools help decide variables such as the number of holes in a mould, the position of the injection point, the pressure required for properly filling a mould or the injection cycle time. Likewise, the kinematic and dynamic simulation allows analysing positions, speeds and accelerations. It also allows calculating the reaction forces in the various standard and critical positions of a mechanism's performance.

The integration of these CAx technologies in the design process allow the engineer to rethink the product definition with performance estimates addressing defined use specifications. The integration of simulation technologies in the design process not



◄▲ Figure 10. Four-hole injection mould project.

only provides a direct improvement on the product obtained but also reduces investment in product prototyping and *time-to-market*.

The challenge for an industrial design engineer is to know how to integrate various functional, ergonomic and formal aspects of the product with the knowledge of the various technical constraints to reach a formally attractive and industrially viable solution.

The knowledge of simulation tools and the proper interpretation of results obtained is thus essential, as well as the knowledge of new manufacturing technologies. This integration results in agile and effective redesign that will lead designers to an optimal product manufacturing solution.

Company and business vision

Given the current economic and social outlook, affected by the severe worldwide crisis that started in late 2008 [UN 2011], it is an advantage for future design engineers to develop an entrepreneurial profile, and not only with the aim of advancing a proper business plan. Global competitiveness [Braun, 2005] drives companies to seek professional profiles that can generate flexible strategies to ensure the company's success and continuity in the global industrial fabric.

The design engineer must understand and manage the factors of creativity, knowledge, innovation, corporate intellectual and material capital as well as the company's vision. They therefore require tools that allow them to interpret the economic, social and industrial environment. They should be able to estimate, since the beginning of the project [Ries 2011] the feasibility of the industrial product to be developed by assessing not only the technical and eco-sustainability aspects (view of the entire life cycle), but also economic, production and commercial aspects.

At ELISAVA, the creation of a business plan for a product or service is considered to be a project that allows future engineers to face working life with a very strong skill set. In undertaking this project future professionals must evaluate and validate product idea hypotheses and the needs covered, studying the business opportunity in the macroeconomic, microeconomic and competitive environment, define the positioning and the perceived product value (marketing plan) analyse the company's industrial and business organisation implications to optimise activities and resources (human and material), address the economic and financial dimension especially creating an investment plan and the type of financing used, all within the current legal framework.

Results obtained

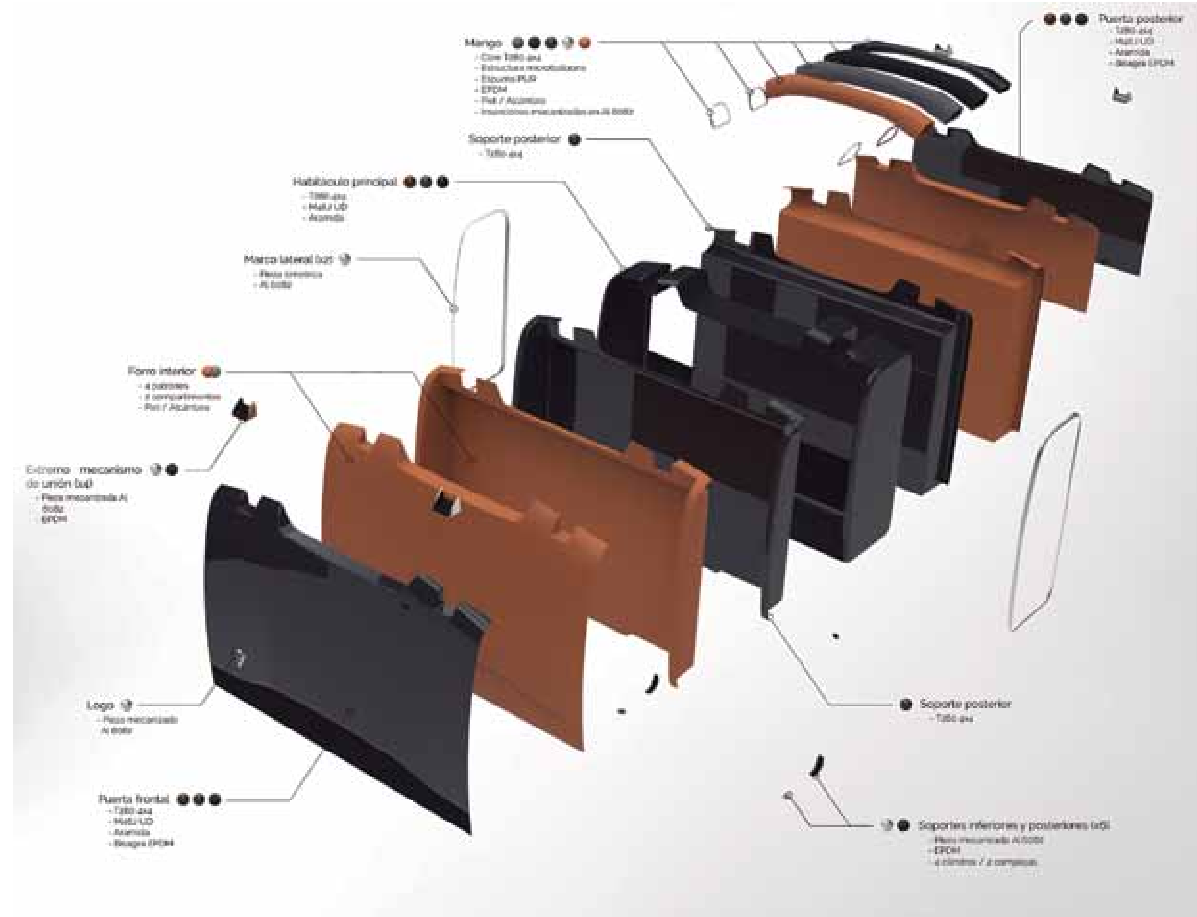
In the ELISAVA design engineering project process, the company has been included as partner and catalyst in the validation of results, with the final aim of taking a qualitative and quantitative leap in product design and development. This enables students to participate in real-life business projects to boost the excellence in their learning process.

VIATOR

Viator is a specialised briefcase for the *business* sector made of high-quality materials such as carbon fibre, leather and alcantara suede. The aim of the project is to launch to market a very functional, aesthetic and lightweight travel accessory.

In this Project, the expression and representation skills acquired have been implemented. Figure 7 shows some exploratory sketches proposing several options in terms of shape, locking and clamping systems in the VIATOR project. The figure 11 also shows how the digital rendering of the briefcase has allowed working on finishing options with a highly realistic appearance.

From the point of view of materials, VIATOR is an example of a project that combines the use of technical and emotional properties. Carbon fibre is left exposed in this product to connote professionalism, *hi-tech* and underscore the high level of engineering of a given product. These emotional properties stem from the fact that it is a tough, lightweight, durable and sturdy material.



▲ Figure 11. Renders and final prototype of the Viator project.

In developing this Project, the collaboration of the Exploded View and Magma Composites companies has been priceless for design advice and validation, the development of parts made of composite materials and the creation of a functional prototype.

In line with the company and business vision, and because it is a product with a commercial future, it has been necessary to create a brand and a name that defines it—*The Carbon Maker*. It is also interesting to note in this project that the first part of the cost study resulted in a retail price much higher than appropriate for the market sector targeted by the marketing plan. This has led to re-drafting the technical project. The material of some parts (side frames) has been changed while a set of pieces (pin bonding mechanism) have been streamlined to lower variable costs.

OXO

The OXO Project is a small wind power generation system. In its initial approach, the product is designed and developed to meet the energy needs of the vessels participating in the Barcelona World Race, although its use could be extended to other areas where wind energy needs to be obtained. This project has solved three key areas: optimisation of the most efficient mini wind generator models to ensure high performance. The support used to attach the wind generator to the vessel was designed and developed and the electrical system cabling was also studied.

To create this product, it has been necessary to include a series of empirical tests, fluid simulation behaviour tests and structural calculations with CAE tools, which have shaped its appearance and have no doubt helped to make most of the technical and formal decisions.

▲ Figure 12. OXO project. Final product renders.

Analysing the provocative design of Dyson fans has also been key, encouraging the authors to achieve a robust solution, but that meets the formal conditions required for the air path to be appropriate in terms of power.

Several companies and organisations have collaborated in this project, such as the company Navitas Paradigma—specialising in the field of renewable energies—, the Barcelona Oceanic Navigation Foundation—organiser of the Barcelona World Race—, FabLab at Les Corts, the City of Barcelona and finally the Fáctil design studio. At Engineering Design in ELISAVA, the collaboration with companies and organisations in Final Degree Projects is a vital and essential aspect that helps give viability and especially to validate the final solutions presented.

▲ Figure 13. OXO project. Exploded view of product components.

▲ Figure 14. Morph communication images. Photograph supplied by kiwibravo, www.kiwibravo.com

MORPH

Morph is a low-cost myoelectric prosthetic hand for transradial amputees (Figure 14). This Final Degree Project has been carried out in the framework of collaboration between ELISAVA and the LEITAT Technological Centre.

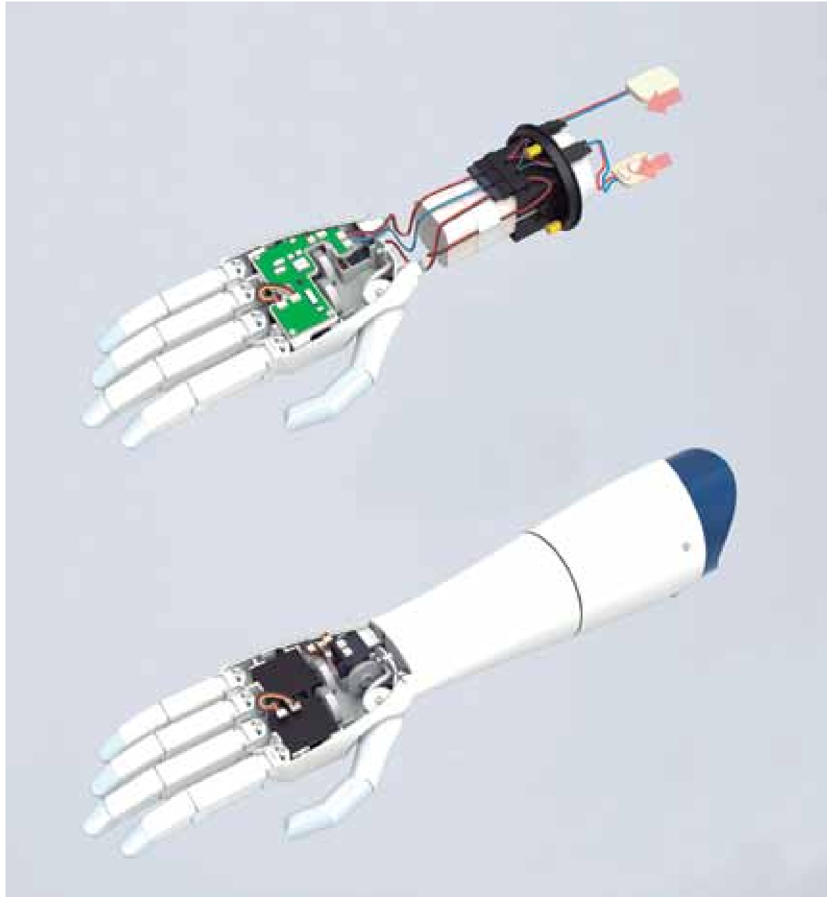
The *briefing* of the Morph project posed considerable challenges: easy to put on and off, customisable to the anatomical conditions of each user, easy maintenance, replaceable parts, equipped with a battery that provides autonomy, and very cost-effective below current commercial prostheses.

In the research phase of the project exhaustive studies were carried out of the biomechanical hand and how it grabs and grasps. This study allows observing the movements to be performed by the prosthesis and work on simplifying it at the mechanical level.

Intensive kinematic and motor testing work was carried out with different 3D printed prototypes, in order to reduced the number of elements (to reduce production cost). Each finger has been synthesized

▲ Figure 15. Section of a finger showing joint design, manufactured of a single piece thanks to additive manufacturing via laser sintering. Photograph courtesy of kiwibravo.

▼ Figure 16. Control of the servo motor that generates movement of a finger triggered by electormyographic signals from muscle contraction and relaxation.



▲ Figure 17. Arrangement of the servo motors and PCB control board on the back of the hand.

in a single piece which includes single interphalangeal joints. Various joint shapes have been devised, prototyped and tested until hitting on the type that allows the required flexing and extension (Figure 15), and which can be controlled by a single strand of nylon (material chosen with a standard material selection process), which doubles as tendons.

The morphology of the palm and back of the hand, and the size of the strands/tendons has been adjusted using structural simulation tools (CAE).

To transmit motion to the finger joints, the prosthesis uses electromyographic signals triggered by the contraction and relaxation of muscles. Figure 16 shows the electromyographic sensors controlling the servo motor which tightens the thread of a finger. In the final product, the processing of the sensor signal is implemented with a specific printed circuit (Figure 17), but in the testing phase it is modelled with Arduino.

In order to facilitate customisation of this product and part replacement, all at a very low cost, additive manufacturing technology via laser sintering was used. It is worth noting how easy it is to assemble the resulting product.

Closing thoughts

In closing, it should be noted that the profile of the design engineer at ELISAVA is that of a professional with design culture who interprets the present while scoping out the future and who trains on keeping an outlook on the scope of the problem to generate, evaluate and build achievable ideas with an entrepreneurial attitude. It is a person who observes, understands and empathizes with the user to propose appropriate solutions for problems detected. They can be said to show integrative thinking. They test and experiment with ease. The Industrial Design Engineering Degree trains competent professionals to design efficiently, becoming essential figures for reducing uncertainty in decision-making at various stages of the project.

Thanks

Thanks to Igor Bregaña and Miguel González (OXO Degree Project), Pol Suriñach (Viator Degree Project), Oriol Bertomeu (Morph Degree Project), Aleix Carricondo, Jordi Domínguez, Oriol Farran and Adrià García (Mould design project) for the work carried out and for allowing use of images of their projects.

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