ISSN 2386-5414
e-ISSN: 2340-8391

Research Article | Artículo de ivestigación

New methods and tools applied for the transfer of knowledge of nanomaterials: A design challenge for Grupo Antolin's company | Nuevos métodos y herramientas aplicadosparalatransferenciadeconocimiento de los nanomateriales: Un reto de diseño para la empresa de Grupo Antolín

Paz Morer-Camo[1]*, Aitor Cazón-Martín[2], Maria Isabel Rodriguez-Ferradas[3], Robert Thompson[4]

[1] Departamento de Mecánica y Materiales, Área de Diseño Industrial. Universidad de Navarra, Tecnun-Escuela de Ingeniería, Manuel de Lardizábal 13, 20018 San Sebastián, Spain. pmorer@tecnun.es ORCID: https://orcid.org/0000-0002-8430-9501

[2] Departamento de Mecánica y Materiales, Área de Diseño Industrial. Universidad de Navarra, Tecnun-Escuela de Ingeniería, Manuel de Lardizábal 13, 20018 San Sebastián, Spain acazon@tecnun.es ORCID: https://orcid.org/0000-0002-9561-5029

[3] Departamento de Mecánica y Materiales, Área de Diseño Industrial. Universidad de Navarra, Tecnun-Escuela de Ingeniería, Manuel de Lardizábal 13, 20018 San Sebastián, Spain. mirodriguez@tecnun.es ORCID: https://orcid.org/0000-0001-8650-6800

[4] Director Científico de MaterFAD. Barcelona. Spain. training@materfad.com

Recieved: 22 de febrero 2023 | Accepted: 4 de mayo 2023 | Published: 29 de junio 2023
https://doi.org/10.25267/P56-IDJ.2023.i3.09

Abstract:

In any product design process, the designer must take into account both the materials and technologies with which he/she must work. Currently, materials and technologies are becoming one of the main elements to foster innovation and add value to final products. Among the many materials, nanomaterials are of particular interest. Nanotechnology is set to play a key role worldwide in the 21st century, as it is a cross-sectoral technology, increasingly relevant to economic fields such as chemistry, medical technology, automotive or food industry. But, if the designer does not know how to work with it and wants to know the scope of this new material, how to transfer this knowledge, related to nanomaterials, from theory to practice? The industry demands experts (designers) who can bridge the gap between theoretical knowledge and practical applications of nanomaterials: products, services and experiences. This article presents a method of knowledge transmission, in which two main tasks can be distinguished: 1) a primary educational component, in which knowledge about new materials and their properties is disseminated in an optimal didactic way, and 2) a second more practical component in which the information is converted into practical ideas and specific applications applied to a challenge proposed in collaboration with the Antolin group.

Keywords: Design Process; Design Education; Industrial Design; New Materials: Nanomaterials; Knowledge Transfer; Workshop

Resumen:

En todo proceso de diseño de producto, el diseñador debe tener en cuenta tanto los materiales como las tecnologías con los que debe trabajar. Actualmente, materiales y tecnologías se están convirtiendo en uno de los elementos principales para fomentar la innovación y agregar valor a los productos finales. Entre los múltiples materiales los nanomateriales presentan un especial interés. La nanotecnología está llamada a desempeñar un papel clave en todo el mundo en el siglo XXI, ya que se trata de una tecnología intersectorial, cada vez más relevante para ámbitos económicos como la química, la tecnología médica, la automoción o la industria alimentaria. ¿Pero, si el diseñador desconoce cómo se puede trabajar con él y quiere saber el alcance de este nuevo material? ¿Cómo transferir estos conocimientos, relacionados con los nanomateriales, de la teoría a la práctica? La industria demanda expertos (diseñadores) que puedan salvar la distancia entre el conocimiento teórico y las aplicaciones prácticas de los nanomateriales: productos, servicios y experiencias. Este artículo recoge un método de trasmisión del conocimiento, en el que se pueden diferenciar dos tareas principales: 1) un componente educativo primario, en el que se divulgan, de una forma didáctica óptima, los conocimientos sobre los nuevos materiales y sus propiedades, y 2) un segundo componente más practico en el que la información se convierte en ideas prácticas, y en aplicaciones específicas aplicadas a un reto propuesto en colaboración con el grupo Antolín.

Palabras clave: Proceso de diseño; Educación en diseño; Diseño Industrial; Nuevos materiales: Nanomateriales; Transferencia de conocimiento; Workshop

Introduction

The importance of materials over the centuries is reflected in how we talk about and recognize ancient civilizations in terms of the materials that were used in those eras. That is why we can recognize them as the Stone Age, the Bronze Age and the Iron Age. Later, after the Industrial Revolution, new materials and new transformation processes began to appear. Polymers, biomaterials and composite materials appeared, giving the product better performance. Nowadays, research continues into new materials, more sustainable materials or materials that are duly modified to give them new properties. We can affirm that materials play a very important role in industrial design since their objective is to create or redesign products with aesthetic and functional characteristics that solve specific needs of people and society. An important key in product design and development is, therefore, the right choice of material to work with in order to achieve the best result. However, what if that material is an emerging material with better characteristics and therefore offers new applications, new and improved designs? But, we do not know how to work with it and how to know the scope of these new materials? We see how advances in the development of these emerging materials are opening up new possibilities for designers. Choosing the right material for a given product can be a complex task, but at the same time a key factor in the success of the product. Materials and technologies are becoming one of the main elements of product design practice as a lever to foster innovation and add value to final products.

Often, when thinking about these new materials, or rather innovative materials, they are studied from a point of view exclusively related to their properties: chemical, physical (mass, weight, volume, density, electrical resistivity, thermal conductivity...), or mechanical (tensile behavior, compression, rigidity, hardness, brittleness, elasticity...). Moreover, they are studied either in relation to industrial practice or in relation to different subjects in the field of education. Therefore, these materials can revitalize design, create new business opportunities, transform industrial activities, and conceive more sustainable solutions and designs that are more creative.

So how to design with and for these new materials? How to understand the scope of new materials? How to transmit the knowledge developed in research centers and in universities to companies? How to make designers aware and give them the right expertise on how to take advantage of the enormous opportunities offered by advanced materials? How to see that design can thus develop its full potential as a driver of innovation and European competitiveness?

A gap can be seen between creative design and the research and development of new materials and technologies to be used in new products. In addition, at the heart of the problem is a lack of collaboration between researchers and the creative industries.

Within the framework of emerging materials, the ones that we have identified as being of particular interest are nanomaterials [P. (Morer, 2020].). Nanotechnology is set to play a key role worldwide in the 21st century, as it is a cross-sectoral technology, increasingly relevant to economic fields such as chemistry, medical technology, automotive or the food industry. It is a challenge for industries to know how to apply nanomaterials and obtain new industrial products with improved properties (anti-graffiti, anti-corrosion, flame retardant, anti-fungal, anti-friction, anti-grease and oil, anti-bacterial, self-cleaning, dry lubricants, polishers, photocatalytic applications, etc.).

The question is HOW to transfer this knowledge, related to nanomaterials, from theory to practice. Industry demands a growing need for experts (designers) who can bridge the gap between theoretical knowledge and practical applications of nanomaterials to develop new products, services and experiences.

This article presents the specific didactic and creative techniques used in a workshop carried out in collaboration with the Antolin Group, manufacturer and supplier of carbon nanofiber helicoidally fibers.

Methodology

Materials and technologies have been seen to be a vitally important topic in Design Education curricula. This area is known to need continuous updates (Zhou et al., 2019). They are in continuous development. Design professionals and students need to continuously acquire knowledge, skills and competences, not only to leverage the possibilities of available materials in their designs but also to contribute to the innovation and development of new materials (Haug, 2018). We have transitioned from a 'hard' profile approach primarily based on science (Ashby et al., 2007) (Myerson Report, 1991), to a 'soft' profile approach that places more emphasis on the didactic approach to teaching materials (Rognoli et al., 2004; Rognoli, 2011; Karana, et al., 2010; Zuo, 2010; Van Kesteren, 2010; Karana et al. 2013), and on "design-led" approaches (Ashby et al., 2007) (Myerson Report, 1991), which involve understanding needs, direct experimentation with materials, and discussion with experts. In this framework, methods such as Active Learning (Bonwell & Eison, 1991) and Experiential Learning (Kolb, 1984) are fundamental approaches to teaching and learning, engaging students in design challenges with companies (Piselli, et al. 2018), and learning through creation (Pedgley, 2010).

It is also observed that R&D areas promote methodologies based on the execution of different workshops, in which didactic-creative programs are carried out, specifically designed to stimulate the creative perception of the participants. It is particularly interesting to find ideal "uses" for emerging materials and related technologies (EM&T) derived from R&D advances in the fields of materials science and engineering.

Among these methods of knowledge transfer we can distinguish two main tasks: 1) on the one hand, a primary educational component, where knowledge about new materials and their properties is disseminated in an optimally didactic way, and on the other hand, 2) where information is converted into practical ideas, suitable for specific applications. While the first task focuses on the dissemination of factual data, relating to quantitative aspects of a scientific nature, the second step is a more qualitative and intuitively inspired means.

Both tasks were carried out within the framework of a workshop, in which a total of 25 students from four European universities (School of Design from Politecnico di Milano; School of Chemical Technology from Aalto University; Material Design Lab from Copenhagen School of Design and Technology; School of Engineering from Universidad de Navarra-Tecnun) and companies from the sector took part. During the workshop, they were presented with a challenge to be solved by a leading company such as Grupo Antolin. One of the first steps focused on the dissemination of the different nanomaterials and their properties. The information was transmitted orally with an extensive supporting glossary on the specific terminologies used to describe the phenomena that can be expected to occur in the nanomaterials sector and the manufacturing processes. Since most of the activity of nanomaterials is not perceptually evident, but in fact imperceptible to the senses, the didactic content covered in the lectures was delivered in a specialized way to allow understanding of the content through explanatory theoretical models supported by various forms of infographic support, delivered in parallel.

2.1. How to get into nanomaterials: Online Course

Prior to the on-site workshop, a first course was held in an on-line format, in which students were introduced to the basic and key concepts related to nanomaterials. This learning course was divided into three parts, as shown in table 1 below:

Part 1: Introduction. This part was divided into three modules:

Module 1: What are nanomaterials and nanotechnology?

It introduced concepts such as what nanotechnology is, what we mean by small, and how can it improve our lives. It also explored how nanotechnology investigates the science and engineering of matter at the nano-scale. Nanotechnology involves manipulating and controlling matter from one nanometer to 100 nanometers. It highlighted the various applications of nanoparticles in sectors as diverse as computing, energy, transport, health and environmental protection.

Table 1. Structure of the on-line course.

When	What	Who	Where
Part 1: Introduction (1-2h) Video presentation of the objective of this activity. · Watching videos (7-10 min each) (TED Talks, YouTube...) Quizzes with questions that can help students increase their understanding of the basic concepts.	Key concepts, inspiring talks.	Tutors	Online - link
Part 2: Question and answer session and homework Conversation or discussion in groups (max. 1h). Discussion with supervisors and/or experts on the videos and materials from Part 1. Preparation of questions for experts	Small group discussions to discuss and explore materials, technologies and cases in more depth	Supervisor Tutors Experts	Online - Meet
Part 3: Collect feedback (max 20 min) Online questionaire	Students Feedback	Supervisor Tutors	Online - link

Module 2: Nanomaterials and their superpowers.

How can we mass-produce sophisticated products with materials that are too small to see?

Module 3: Risks of nanomaterials.

Safety risks of nanomaterials: Are engineered nanoparticles dangerous? Moreover, if they are, how do we assess the health risks and ensure their safety? [A. (Ramanathan, 2019])

Figure 1 shows the information provided in the online course, allowing students to follow the suggested learning order. Throughout this pre-course, students had the opportunity to engage in group conversations and discussions with experts in Nanomaterials from the NanoGune center (San Sebastian) and MaterFad (Barcelona).

2.2 Nanomaterials workshop

2.2.1 Work plan

The work plan for the workshop is shown in Figure 2. During the workshop, multidisciplinary teams were formed, consisting of designers and engineers from different European backgrounds. The workshop was structured to ensure efficiency and validity in the process, focusing on the quality of input and effective communication of proposals. Creativity was stimulated using techniques suitable for a multidisciplinary audience. The objective was to explain complex concepts through stories and images, assessing their applicability in the creative process. The participants started generating ideas by applying the knowledge they had acquired, aiming to incorporate the principles related to the physical and chemical behavior of various nanometric materials into tangible concepts.

During the beginning of the workshops, students were informed about the expected outcomes of their teamwork. These outcomes included a final presentation, a physical prototype of the solution (if possible) and a poster. These results were valuable for dissemination activities that emerged from the new methods.

Regarding the presentation, each team was required to prepare a concise 10-15 minutes presentation for the last day of the workshop, in which they would explain their proposed solution. This presentation was directed towards the company that had posed the challenge, allowing them to comprehend the solution and provide feedback to the team.

Regarding the prototype, students were tasked with creating a physical prototype of their solution to complement the oral presentation. The ease of creating prototypes varied depending on the specific solution and the related EM&T.

Figura 1. Información suministrada en el curso on-line

UNDERSTANDING EM&T DISCOVER Introduction/learning EM&T	EXPLORING EM&T DEFINE Ideation/Concepts	APPLYING EM&T DEVELOP Selection/Mockups low fidelity	APPLYING EM&T DELIVER Applying	PRESENTATION
Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
9.00 Welcome	**9.00 Define**	**9.00 Develop**	**9.00 Deliver**	**9.00 Deliver**
City, University	*Market/competitor analysis*	*Concept selection*	*3D models*	*High Fidelity ptorotypes*
Students introduction	*Creativity*		*High Fidelity ptorotypes*	*Materilas*
9.30 Present workshop	MindMap	**9.30 Develop**	.	*Concepts*
Objectives	BrainStorming	*Concept selection*	.	*Concept presentation material*
Agenda	Técnicas TGN	*Low fidelity prototypes*	**10:00 EM&T Pill (Company 04)**	
	.	.	*Graphenea*	
10:30 Coffee Break			.	
10:45 Understand EM&T	**11.00 Define**	.	.	**11.00 Preparing presentations**
Theory	*Sketching, drawings*	.	.	
Robert Thompson	.	.	.	
	11:30 EM&T Pill (Company 02	.	.	
12:15 Company 01	*Burdinola*	.	.	
Briefing presentation		.	.	**12:30 EM&T Pill (Company 05)**
Launch Challenge		.	.	*Ceit*
Antolin Group		.	.	
13:15 - 14:15 Lunch			.	
14.15 Exploring EM&T	**14.00 Define**		.	**14.00 Final presentations**
Experimentation of EM&T 30'x4=120'	*Sketching, drawings*		.	*15 min group*
Practices in lab		**15.00 EM&T Pill (Company 0**	.	*Exhibition*
Toolkit		*Ikerlat*		*Evaluation*
Robert Thompson	**16.00 Presentation**	**16.00 Presentation**		
	5 min group	*5 min group*		**16.15 cuestionario final**
16:30 Groups				**16.30 Closing**
17.00 End of session				

Figure 2. Workshop work plan

For the poster, each team designed a poster using a template provided by the researchers at their respective university. The template included sections in which the team described their project, the extents of EM&T involved and the level of the market-related proposal preparation.

The following sections present the most significant milestones achieved during this workshop.

2.2.2 Exposing the challenge: On-site workshop

The students who participated in the workshop were enrolled in the final years of their degree courses at the four European universities involved, specializing in design and engineering. The workshop focused on a challenge presented by Grupo Antolin. Initially, Grupo Antolin a mechanical workshop in Burgos, Spain, founded by Avelino Antolin Lopez and his sons Avelino and Jose, specialized in vehicle and agricultural machinery repairs.

Today, Grupo Antolin has evolved into a leading multinational company engaged in the development, design, and manufacturing of interior components for the automotive industry including Headliners, Doors, Lighting, Cabins and Consoles. It operates in 26 countries, employing over 30,000 individuals who contributre their talents to the company's success. Creativity, leadership and customer satisfaction remain fundamental values for Grupo Antolin, driving its future achievements.

Nanomaterials specialists delivered the opening lectures from Grupo Antolin, who provided detailed insights into the nature and behavior of nanomaterials. Significant emphasis was placed on an in-depth exploration of GANF carbon nanofibers, which were specifically provided by the Antolin group. Following the presentation, Antolin presented the challenge to the participating students. While the primary focus of the project on innovative applications of carbon nanofibers in vehicle interiors (Antolin's main area of industrial expertise), alternative and unrelated innovations were also encouraged, seeking potential applications in completely different sectors such as packaging or agriculture.

2.2.3 Didactic pills during the workshop

As the workshop progressed, participants were given the opportunity to explore additional principles related to nanomaterials in general. This was achieved through educational "pills" provided by prominent companies specializing in different applications of nanomaterials (as listed in Table 2). The selection of these "pills" was strategic, aiming to offer participants a comprehensive understanding of various aspects related to nanomaterials. The goal was to expand their knowledge of potential applications while also highlighting the limitations and safety requirements associated with working with nanomaterials. The "pill" sessions covered diverse aspects and fields of application and research, ranging from medicine and energy production to nutrition and nano-electronics.

2.2.4 Toolkits

The didactic content presented during the conferences was accompanied by a series of individual materials toolkits, which were created for public use. These toolkits were organized in the form of a box folder, containing samples of materials (see Figure 3), as well as a collective set of quick reference information guides (see Figure 4). These kits were developed as part of the DATEMATS project, with the aim of showcasing the properties of the four materials selected by each of the four participating universities in the project [more information at https://www.datemats.eu/toolkit/].

Each box within the toolkit represented a specific material and included accompanying brochures that outlined its properties, production methods, usage, safety hazards, and technology readiness levels. The toolkits played a critical role in the workshop methodology and were subject to evaluation, as they addressed a gap in the design field that combines didactic and creative elements (Piselli et al., 2018a). In the field of materials science, where innovation often faces challenges due to a lack of knowledge and access to reliable information sources, the toolkits aimed to serve as user-friendly references that bridge this gap and enable a more confident application of materials with a higher degree of inspiration. The toolkits were designed to provide both sensory and intellectual inputs, achieved through physical samples of materials and explanatory literature, respectively.

A small sample of the material was placed within a central void of the box , allowing users to touch the material and assess its sensory qualities. Surrounding the sample were several information blocks containing logistical and identification details, such as the trade name, class and manufacturer's contact information. The materials were also characterized by their available formats, colors, finishes and physic-chemical profiles... The primary purpose of the property classification tables was to provide users a quick qualitative visualization of the material's relative and comparative qualities in each distinctive property; ultimately, this allowed users to intuitively extrapolate one or more applications of the material with confidence.

2.5. Nanomaterials presented at the workshop

The students were introduced to four nanomaterials: 1) GANF, 2) Bionox, 3) Grafylon and 4) Nanotex. These nanomaterials were chosen to showcase a wide range of nanoparticle applications in the automotive sector.

1. GANF (carbon-based graphene oxide nanofibers) are submicron structures with an elongated aspect ratio and a total length of less than 100 gauge. They possess

Table 2. Companies participating in the Workshop.

Graphenea https://www.graphenea.com/	**Ikerlat http://www.ikerlatpolymers.es/?lang=es**	**Ceit-BRTA https://www.ceit.es/**	**Burdinola https://www.burdinola.com/es/e**
Producer of high quality graphene. Design, manufacture and supply graphene-based chips and materials for your industrial and research needs.	EsSpecialists in the development and manufacture of customized polymer particles. Today, with a track record of fifteen years, the company has established itself as a benchmark in the polymeric dispersions market..	CA non-profit research center whose main activity is to carry out research projects in collaboration with organizations. Among other fields, they research on bio-applications of nanomaterials.	One-stop provider for working safely with nanomaterials. They carry out the safest and most efficient laboratory projects in the world, laboratories where researchers enjoy working to make the world a better place.
This company brings knowledge about graphene as the lightest and strongest material, with the ability to conduct heat and electricity and to be integrated into a wide range of applications.	This company provides knowledge on the customized manufacture of nanoparticles used as coatings or for clinical diagnostics.	Ceit provides knowledge on micro and nano applications in the bioengineering sector.	This company provides knowledge on the equipment needed to work safely with nanomaterials, adding value in the development of industrial processes in the automotive industry.

Figure 3. Sample of boxes of materials

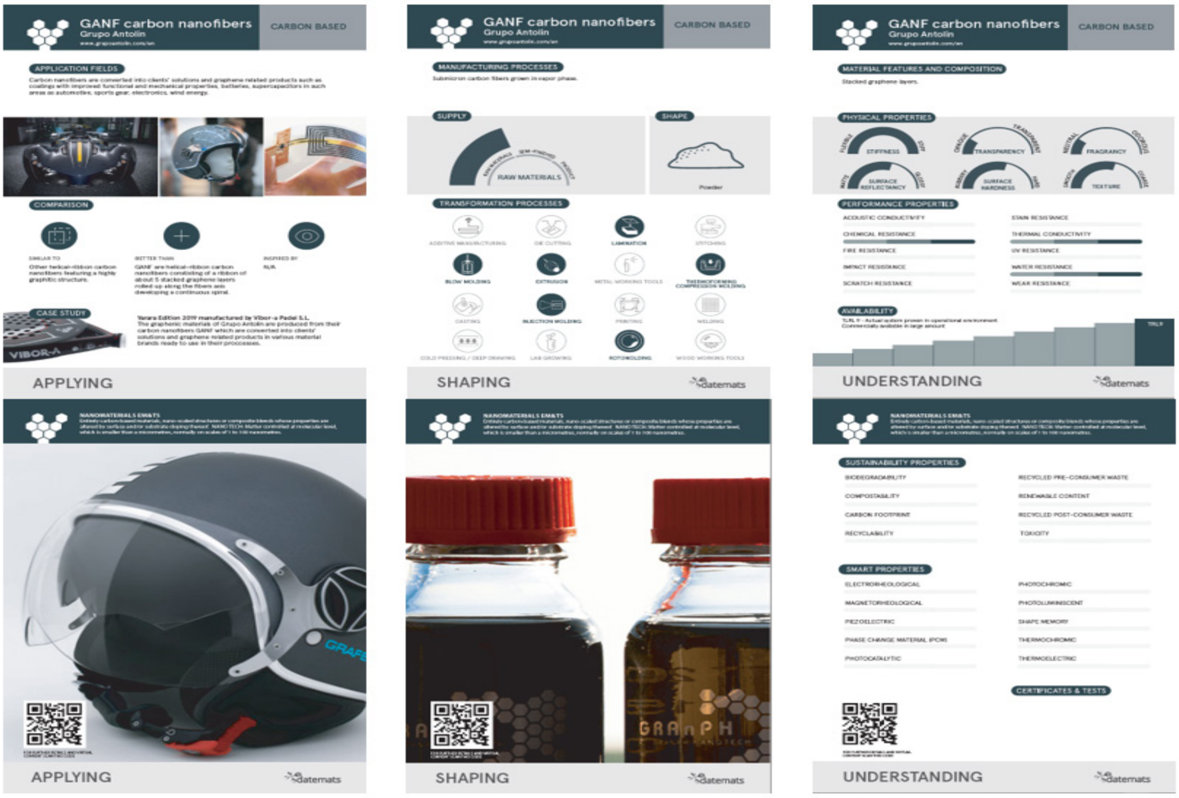

Figure 4. Sample brochures with information on various nanomaterials ©Datemats-Materialy

high toughness and tensile strength, which allows them to material substrates for functions such as for filtering, high surface hardness, and corrosion protection. , depending on the concentrations, can provide several different. Additionaly, GANF can conduct heat and serve as a substrate for improving electronic conduction or optoelectronic capacitance by depositing other metals on them.

2. Bionox, produced by Apta Colour, are nano-sized TIO2 particles from 10 to 100 nanometers. These particles impart photocatalytic properties to materials. Photocatalysis is an optochemical phenomenon in which TIO2 pigments, when exposed to sunlight and surrounded by oxygen; acquire catalytic capabilities, accelerating the mineralization of certain pollutants to oxidized states. TiO2 particles also possess surfactant properties that enhance antifouling properties and prosses bactericidal effects. They can also possess surfactant properties that enhance antifouling properties and possess bactericidal effects. They can also modify the rheology of viscous liquids for industrial applications.

3. Grafylon produced by Direct Plus, is a PLA polymer-based filament composite with a low volume fraction of graphene nanostructure within its matrix. Graphene is known for its high mechanical strength and electrical and thermal conductivity.

Even at low volume fractions, graphene within polymer substrates offers advantages, such as good dispersion, thermal dissipation, excellent mold reproducibility, and integrality in electrical structures. It also provides improvements in surface hardness, impact resistance and crack propagation resistance, even at lower temperatures.

4. Crypton's Nanotex is a SiO2 nanoparticle additive that can be embedded in textile fiber matrices to create a water-repellent and highly resistant coating, preventing water absorption. SiO2 particles can be applied to textiles using various methods, improving their lifetime by acquiring anti-fouling properties and self-cleaning capabilities due to the superhydrophobic nature of SiO2 nanoparticles.

Given the emphasis of GANF among the nanomaterials, the focus of exploration was on its potential applications in various sectors with innovative need and impact. The different groups received specific input to generate ideas in four different areas: energy, food, and biology and pollution control.

Outcomes

In addition to the more tangible results of the workshop, such as posters and presentations (see Figure 5), students were also requested to complete a questionnaire to evaluate various aspects of the workshop.

With regard to the methodology, the students felt that it was appropriate and the workshop format useful for working with new EM&Ts. However, they did highlight several problems inherent in the EM&T of the workshop. The first problem with nanomaterials is their "invisibility" and associated phenomena. Most of their activity is, by virtue of the scale and speed of action, imperceptible to human senses and their experimental understanding requires expensive, specialized laboratories and expensive equipment. This is why having experts in these fields collaborate and make "simple" something that is complicated in itself has proved to be a

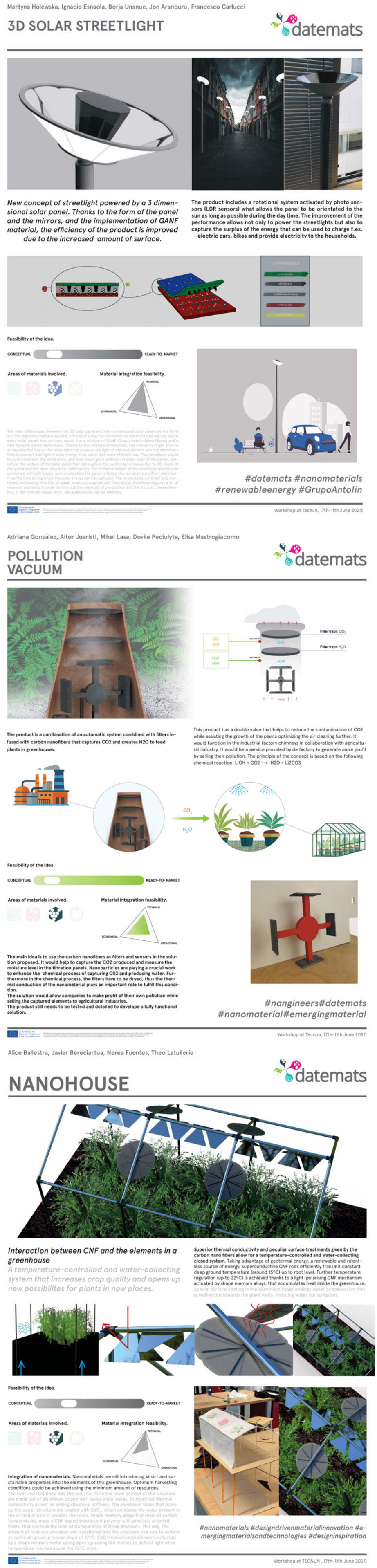

Figure 5. Images of some final posters

great experience. The role played by the nanomaterials experts and the dialogue they establish with the students in the activities was one of the aspects most valued by the students. When asked what the most valued aspect of the workshop was, some of the responses were: I value Robert a lot. He was incredibly helpful. Most valuable was the flood of knowledge from Robert. Having a person like Robert to guide us, work with a new technology that is not realistically applicable now. The expert helped the students to evolve from very abstract ideas about nanomaterials to a more comprehensive understanding of the phenomena behind their "superpowers". The use of pictorial diagrams and videos showing the production methods of nanomaterials helped the experts to link storytelling to help pupils assimilate the new knowledge and fill in their ontological and linguistic gaps.

With regard to the physical kit of materials, its evaluation by the students was very positive (90% gave it a score of 5) although they missed a digital version to consult it outside the workshop. It was confirmed that the bibliographical information provided in the kit sheets was very easy to understand (68.2% rated it a 5 and 18.2% a 4).

Finally, the participating companies, both by issuing a challenge to the students and by sharing with them the knowledge pills about their experiences, was key for the students. In a way, from the experiences lived by companies from different sectors and contexts, in their journey towards the development of industrial solutions based on nanotechnology and their trial and error story shared with the students, a library of "lessons learned in the skin of others" was generated. This body of experiential knowledge transferred to the students compensated for the impossibility of having their own practical experiences. The students realized how nanomaterials are an area of growing interest to many innovative companies from a wide range of different sectors that can contribute to their employability in their future careers.

Conclusions

Throughout this work, we have significance the significance of selecting the appropriate material during the design process of a new product. When this material is an emerging one, possessing properties that make it an ideal choice, comprehending its characteristics becomes challenging. It is highly intriguing to engage in a collaboration with leading companies in these fields and tackle such challenges.

In the case of nanomaterials, "practical skills" are not solely related to the technical or experimental abilities of a designer or engineer, unlike other cases of emerging materials. Instead, they are focused on "social skills". Nanomaterials knowledge is highly interdisciplinary, encompassing disciplines such as applied physics, material science, physical chemistry, condensed matter physics, biochemistry, molecular biology, and polymer science and engineering. In this context, the role of the designer, as a facilitator, translator and coordinator becomes essential in integrating diverse areas of knowledge related to nanomaterials. This integration is crucial to transform nanotechnology's potential into marketable products and applications. The "soft skills" develop by students through our method, can be described as the ability to establish a multidisciplinary dialogue and translation processes with the goal of developing innovative nanotechnology-based functions for a product or application.

To enhance the formative aspects, additional tools can be incorporated alongside the toolkit presented in the workshop. This can involve the development of physical or digital gamification tools that provide students with a more experiential and interactive way to understand and learn tools that provide students with a more experiential and interactive way to understand and learn about the different phenomena associated with nanomaterials and their potential applications.

Acknowledgements:

This work has been carried out within the framework of the Erasmus+ funded project DATEMATS: Knowledge &

Technology Transfer of Emerging Materials & Technologies through a Design-Driven Approach.

References:

Ashby. M., Shercliff, H., Cebon, D. (2007). Materials Engineering, Science, Processing and Design. (4th Edition - November 27, 2018) https://www.elsevier.com/books/materials/ashby/978-0-08-102376-1

Charles C. Bonwell, James A. Eison, (1991). Active learning: Creating excitement in the classroom. Washington, DC: School of Education and Human Development, George Washington University.

Haug, A. (2018). Acquiring materials knowledge in design education. International Journal of Technology and Design Education, (February), 1-16.

Ilse Van Kesteren, (2010) A User-centred Materials Selection Approach for Product Designers, Middle East Technical University Journal of the Faculty of Architecture 27(2) DOI:10.4305/METU.JFA.2010.2.18

Karana, E. , Pedgley, O., Rognoli. V. (Eds.). (2014). Materials Experience: fundamentals of materials and design. Butterworth-Heinemann https://doi.org/10.1016/C2012-0-02198-9

Karana, E., Hekkert, P., Kandachar, P. (2010). A tool for meaning driven materials selection. Materials and Design, 31(6), 2932-2941. https://doi.org/10.1016/j.matdes.2009.12.021

Kolb, D. (1984). Experiential learning: Experience as the Source of learning and development. Englewood Cliffs: Prentice Hall.

Morer-Camo, P., Cazón-Martín, A., Fernández-Ferradas, M.I., & Thomson, R. (2020). Chapter 2. Nanomaterials. Emerging Materials & Technologies. https://series.francoangeli.it/index.php/oa/catalog/book/556

Pedgley, O. (2010). Invigorating industrial design materials and manufacturing education. METU. Journal of the Faculty of Architecture, 27(2), 339-360.

Piselli, A., Baxter, W., Simonato, M., Del Curto, B., & Aurisicchio, M. (2018b). Development and evaluation of a methodology to integrate technical and sensorial properties in materials selection. Materials & Design, 153, 259-272.

Piselli, A., Dastoli, C., Santi, R., & Del Curto, B. (2018a). Design tools in materials teaching: bridging the gap between theoretical knowledge and professional practice. In DS 93: Proceedings of the 20th International Conference on Engineering and Product Design Education (E&PDE 2018), Dyson School of Engineering, Imperial College, London. 6th-7th September 2018 (pp. 193-198).

Ramanathan, A. (2019). Toxicity of nanoparticles_ challenges and opportunities. Applied Microscopy, 49(1), 1-11.

Rognoli, V. (2004). il materiali per il design: un atlante espressivo-sensoriale [Materials for design: an expressive-sensorial atlas]. PhD Thesis. Politecnico di Milano.

Rognoli, V. (2011). A Broad Survey on Expressive-sensorial Characterization of Materials for Design Education. METU Journal of Faculty of Architecture, 27(2), 287–300. https://doi.org/10.4305/metu.jfa.2010.2.16

Zhou, Z., Rognoli, V. (2019). Material Education in Design: from Literature Review to rethinking. Insider Knowledge, DRS Learn X Design Conference 2019, 9-12 July, Ankara, Turkey. doi.org/10.21606/learnxdesign.2019.17078

Zuo, H. (2010). The selection of materials to match human sensory adaptation and aesthetic expectation in industrial design. METU Journal of the Faculty of Architecture, 27(2), 301–319.

Funding source / Fuente de financiación

This work has not received any funding. /
Este trabajo no ha recibido ninguna fuente de financiación