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From Science to Design: the Design4Materials virtuous cycle

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Abstract: Despite the large number of innovative materials developed in laboratories worldwide, their application in new mass-produced products is complicated. Design can reduce the risk that the research developed in scientific laboratories could fail to be properly exploited and triggering a beneficial cycle linking Science to Design. This paper present the Design4Materials, an italian network founded by the laboratories of leading schools of design: MaterialdesignLab|Sapienza Rome, Madec|Politecnico di Milano, HybridesignLab|SUN Naples, Soft Surfaces and Polisensoriality|Poliba Bari.
After presenting the different skills of the network members, the authors describe the capabilities and the goals of the network and the main results developed like the project that define characteristics and identities for an open material, starting from a research of the IIT of Genoa. The Design4Materials aim is to play a leading role on design-driven innovation process, responding to society's changing needs and developing a 'circular' methodology of innovation from a design standpoint.

Keywords: Materials, Design&Science Network, Design driven innovation, Sustainability, Bio-based materials

1. Design and Material Science

The design industry has always been extremely interested in Science – mathematics, biology, physics, chemistry, and particularly the chemistry that concerns itself with materials – from which it has deduced and hybridised methods, approaches and results with the aim of translating the progress made by research into products and innovative concepts (Cecchini, 2004, p. 16; 2005 p. 20; 2015, pp.51-53; Ferrara, 2009. Ferrara et al, 2009. Lucibello, 2011. Carullo et al, 2014a; 2016c).

Nevertheless, despite the large number of materials developed by scientific laboratories, their application in new serial manufacturing processes leads to many complications. The long timescales

required by industrial development are combined with the difficulty of making materials attractive and competitive enough for the market, envisaging suitable applications for them. In such circumstances, design takes on an important role because it 'closes the cycle of innovation', establishing design scenarios and concepts for future materials that can attribute scientific and technological research with value and meaning of innovation (Ferrara, 2010; 2015; 2016; Ferrara et al, 2015).

Designers, who are skilled at handling technical and conceptual work, are indeed highly capable intermediaries linking scientists and users as well as manufacturers and consumers. Indeed, as regards the common practice of limiting useful design processes to the final phase of technical development (as an opportunity to improve a product's aesthetic value), today it is generally appreciated that design is also important during the material development phase, thanks to its ability to stimulate and guide innovation during processes that are specific to scientific procedure (Ferrara, 2010; Langella, 2012, p. 23; Lucibello et al, 2015).

In 2015, these conditions gave rise to the Design4Materials network, set up with the aim of making an original contribution to the creation of real, proactive cooperation between Science and Design. This network links Italy's most prominent design schools (the MaterialdesignLab|Sapienza University in Rome, HybridesignLab|SUN Second University in Naples, Madec|Polytechnic of Milan, and Bari Polytechnic's Soft Surfaces and Polisensoriality, or SSP, project) with research centres (such as the CNR National Research Council, the Città della Scienza science centre in Naples, the CETMA Engineering, Design and Materials Technology Centre in Brindisi and the IIT Italian Institute of Technology), as well as Italy's museums (such as the Plart Foundation in Naples) and, of course, the national manufacturing industry.

2. The Design4Materials network

2.1 A network of networks

Design4Materials is a network of networks that was set up to integrate the expertise and experience gained by many different Italian research groups working in the field of material design so as to create an opportunity for exchange, cooperation and cross-fertilisation that could be recognised as a coherent and flexible benchmark system for companies and research organisations.

The strong interaction between, and hybridisation of, scientific methodologies (deductive-logical-analytical) and those of the design field (inductive-experiential-summarising) create the beneficial cycle that links scientific research to the design of applications and that, starting with newly emerging needs, can generate innovation in the field of materials both in terms of features and sensory-aesthetic value.

The Design4Materials network puts itself forward as a proactive body and a network of researchers that aims to link different kinds of know-how in the field of materials so as to build a research and experimentation centre of excellence that can trigger innovation.

2.2 Background

Design4Materials is therefore based on the well-established background of skills and know-how built up by each of its members, each of which is a de facto network in itself, operating in its own area and at a national level from north to south.

To be more specific, below is a list of the most important projects developed from 2000 up to now by each single network:

- Sapienza University’s MaterialdesignLab in Rome (founded in 2013), is a ‘space for multidisciplinary action’, featuring a permanent creative design laboratory where new scenarios aimed at developing products that can improve people’s daily lives are explored and hypothesised, as well as a physical material library. One of the MdLab’s main aims is to promote scientific research in the field of innovative materials, with a view to applying the results of theoretical and experimental research to new products of a high technological, typological and creative level with improved features. The Rome organisation’s two main strands of research are, firstly, its work on the visual and sensory characterisation of materials and, secondly, the creation and use of environmentally friendly materials.
  The first strand involves experiments conducted on the textures of materials in order to maximise the aesthetic worth of their surfaces and the study of colour aspects, with the aim of creating particular identities by recovering, among other things, typical Italian values. In fact, the creativity is linked to products, and the combination between materials and techniques can be seen as DNA double helix, agents of heredity of places and cultures. The innovation value chain starting from knowledge, sharing and reactivation of elements of identity, in a new Italian (and European) network of exchange.
  The second strand, which concerns research into environmentally friendly materials, involves the study of materials made from food waste, so as to create manufacturing processes that can be set up in small, specially designed production plants. Such experimentation hopes to identify design scenarios and innovative product concepts, not only taking its cue from the features of this enormous and as yet little-known family of materials, but also from the definition of specific stylistic and expressive identities that can expand their possible fields of application and identify new product concepts. The main results developed to date thanks to the network’s action are the definition of new palettes or scales of innovative materials, starting from the scientific research of IIT and of other scientific and productive institutions the network works with; the definition of applicative scenarios for these materials; the identification of product concepts responding to society’s changing needs and the advance of productive technologies; the raising of interest in new materials and of participation in their definition from a design standpoint, by integrating communication strategies into the methodology; and the continuous evolution of the ‘circular’ methodology of innovation shared between Science and Design.

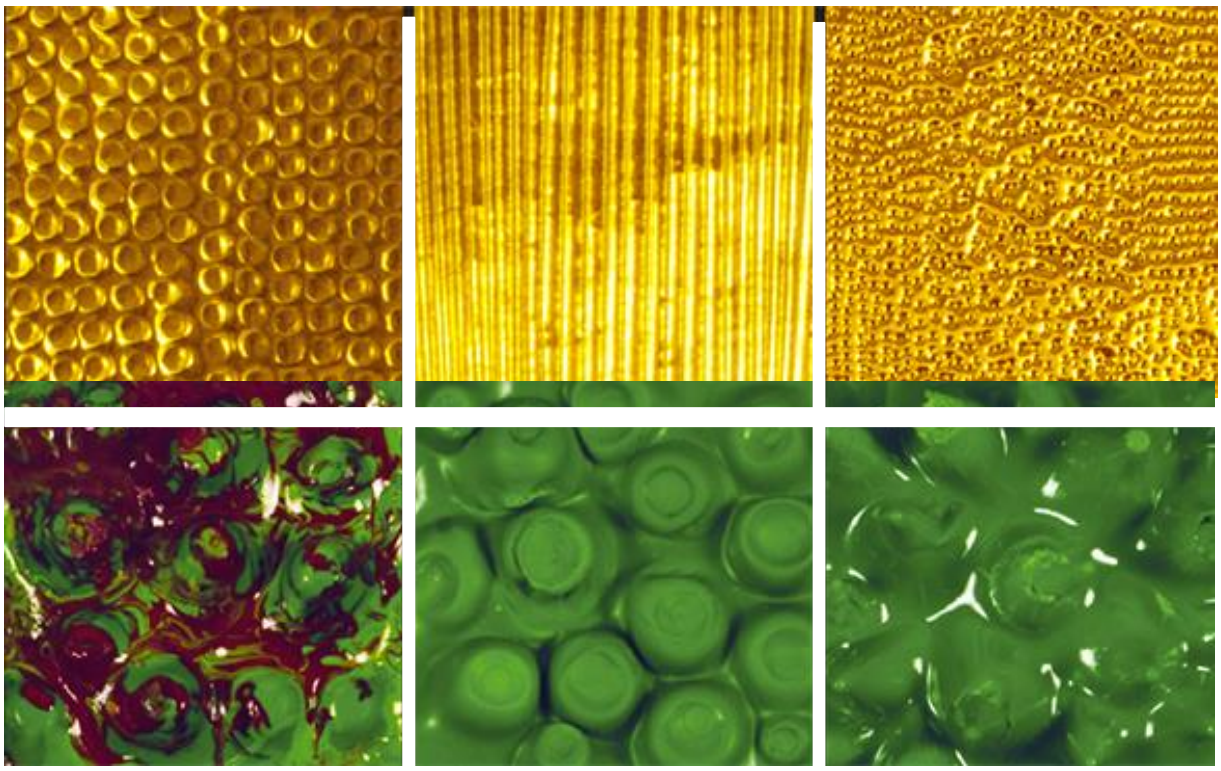

Figure 1. Examples of the aesthetic-perceμtive 'characterisation' of materials (copper; silicone), students of Technology and Design I – Sapienza University, Rome, proff. Cecilia Cecchini & Sabrina Lucibello, 2013-2014.

- The laboratory has also set up a partnership with Genoa's IIT for applying the patents developed by the Smart Material Group headed by Athanassia Athanassiou, particularly its biorubber patent WO2015/004593 (Italian patent no. TO2013A000570), which is particularly interesting due to the various different possible applications these materials could have which, thanks to their silicone binder, are quite tenacious and can therefore be applied in a range of different industries.
- The Soft Surfaces and Polisensoriality, or SSP, lab at Bari Polytechnic's DICAR Department of Civil Engineering and Architecture operates in the Puglia region's industrial sector with a particular focus on textiles. It has several ongoing partnerships with companies that aim to improve the perceptive-sensory aspect of textile surfaces both in the fashion sector –working with major companies in that industry (Mafrat) (Carullo et al, 2014a, 2016a) – as well as in the high-tech workwear sector (Innex), in partnership with Rosa Pagliarulo. The SSP also works with research centres that focus on local materials such as the CETMA Engineering, Design and Materials Technology Centre, where it collaborates on the MAIND PON (National Operational Programme) project. The methodology involves a quantification process that uses tools tested in partnership with Giovanni Pappalettera and Vincenzo Moramarco from Bari Polytechnic's DMMM (Department of Mechanics, Mathematics and Management). Sensory properties are quantified at levels that are useful to human physical perception according to ten gradients (following the NCS system). Objective figures are attributed to each gradient along smooth-rough, soft-hard, transparent-opaque pairs and so on. Once the scales of materials are established, the process moves on to construct more complex scales where particular actions or production processes are applied to materials, and the changes to surfaces as regards perceptive parameters are analysed. Last but not least, the scales are crossed with different parameters.

Finally, a specific visual shows the characteristics of comfort or discomfort of the material’s ‘skin’, the final interface with users and consumers (Figure 1). Using this methodology, it was recently possible to export the sensory/perceptive potential of processed wool fibres from the Gentile di Puglia breed of sheep to the international fashion trend industry at NYTM, New York Textile Month 2016 (Carullo et al, 2016b, 2016c).

Figure 2. Examples of the aesthetic-perceptive ‘characterisation’ of biorubber, patent no. WO2015/004593, Sapienza University, Rome – the IIT in Genoa, Sabrina Lucibello, 2016.

Figure 3. Tactile scales (student: Michele De Chirico): a scale of smooth-rough parameters in seven gradients; scales of interaction between smooth-rough and soft-hard parameters, with the introduction of processes and materials. The graph highlights the levels of comfort or discomfort of soft elements (woollen fibres) on a smooth and rough base.

Figure 4. Tactile scales (in the workshop with Rosa Pagliarulo – students: V. Vitale and V. Saponari) of variations in the roughness of Gentile di Puglia sheep breed woollen fibres in gradients, finalist prototypes at the Dorothy Waxman International Prize, displayed at the NYTM, September 2016.

- Hybrid Design Lab is a research, design, and teaching laboratory at the Department of Civil Engineering, Design, Construction, and the Environment at Seconda Università degli Studi di Napoli. Founded in 2006, it is geared towards testing the relationship between design and science. One of its main areas of action consists of transferring the theoretical, experimental and technological research amassed in the new materials sectors to the planning sphere, in designing innovative and sustainable products and services.
  HDL's activity is developed in various directions, from research financed with European, national, or regional funds, to design for businesses, and teaching workshops. In the lab, designers and scientists work together to make mutual and one-to-one contributions.
  For this one-to-one work to be achieved, it is necessary to grapple with and overcome the limits and obstacles connected above all to how distant the scientists' and designers' objectives, times, and languages are from one another. The partners recruiting phase, therefore, cultivated interests and expectations in common with experts and research centres specialized in materials science, in order to encourage all players in the process towards cross-pollination, and thus towards acquiring open, cooperation-oriented attitudes.
  The activities carried out include projects in which design interprets and applies the new materials developed by scientists while making the most of their quality from a design-driven standpoint. They also include design work on material through the development of new materials designed jointly with laboratory scientists, and direct experiences of making new materials with a DIY perspective.
  Through workshops, PhD programmes and university theses, the HDL laboratory trains hybrid designers, defined as "in-Lab designers," who do their design work in chemical and materials engineering laboratories. In these experiences, designers do the research and experiments that are the basis for developing new materials. And they do this on their own, while introducing new approaches and viewpoints

connected with their design skills and their knowledge of what markets and evolving lifestyles need. HDL’s designers discover the scientific method, and the rigour of experimentation and of the protocols followed in accordance with objective criteria. But they do so while using their own tools linked to creativity, intuitiveness, and multimodality, and to the ability to shape and pre-shape. This makes them participants in the landscape of materials while bringing alternative contributions and stimuli as well as introducing new paths, parallel visions, and uncustomary detours to the research done by chemists and engineers.

The results of the research conducted in this direction have been put on display in several national and international exhibitions at Città della Scienza (Naples), Festival della Scienza (Bergamo), the Shenzhen Convention and Exhibition Centre, and the Campus Center Galleries of the California College of the Arts in San Francisco.

- MADEC is the Research Centre of Material Design Culture at the Design Department of Politecnico di Milano. Its mission is to conduct and foster theoretical and practical-experimental research on design for material, evolutions of material culture and design paradigms. The centre collaborates with various institutions and companies. Among them: the Fondazione Giannino Bassetti (for the ethics of material research), the Città dell’arte Pistoletto Foundation (for the sustainable conversion of production), Assocompositi and Lecco Innovation Hub. MADEC’s researches reserve a special attention to smart materials and composites for interactive products, as well as tools and methods for design-led innovation, with the aim of facilitating designers facing the challenges of technical evolution.

  MADEC takes into account the need for systematic and interdisciplinary dimension of innovation processes and adoption of a new material. It helps to define the system of the actors of innovation (collaborators, partner companies, research centres, etc.) to open up innovation involvement, which goes beyond those usually established, and allows unhinge mechanisms and established models. In this process, the design expertise also acts as mediator between the various actors, and works to improve the dialogue and translation of specialist language of disciplines, for example, to switch easily from the quantitative to the qualitative understanding of the users’ experience. MADEC operates in the spirit of Open Innovation (Chesbrough, 2006) developing open tools and exploring processes in order to share knowledge.

  The MADEC contribution to the Design4Materials network deals with the complexity of a product/material R&D design-lead process, were many and very different actors are involved, through the DdMIM (Design-driven Material Innovation Methodology), referring to the European Community’s definition of creativity-driven material innovation. DdMIM has been validated in 2015 and presented to the international scientific community (Ferrara, 2016; Ferrara et al, 2016), as well as other activities of the research centre (Lecce, 2015). Today DdMIM is diffusing, thanks to the "Design for Enterprises" cycle of courses (which contains the dedicated module "Design for Materials"), promoted by the European Community with the aim to improve the innovation capability of European SMEs.

  Compared to the traditional approach of R&D material process, the MADEC’ methodology anticipates sensoaesthetic, somaesthetics and perception studies, as well as sensemaking, envisioning storytelling, considering these entire fundamental to a customer consensum to a new material. This approach puts a strategic focus to the user’s experience and the meaning that a material assumes, in order to evaluate the

innovation adequacy and make it more relevant according to consumer values. That's why, during R&D, the characteristics of materials are explained from several points of view: the sensory experience, aesthetics languages elements, the cultural perception. The skills involved, in addition to design and materials science, are ethnoanthropology, pragmatic aesthetics, and sociology, that allow to expand the "design discourse" to understand the change in society and to draw the future perspectives for material design.

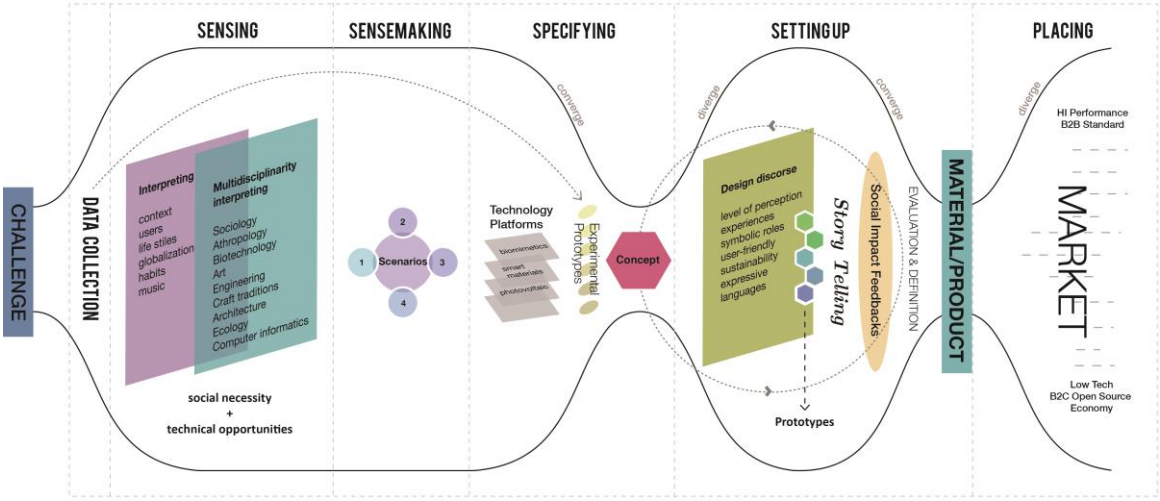

Figure 5. The DdMIM scheme. Copyright by MADEC, Politecnico di Milano

2.3 A circular methodology

Design4Materials network is an active tool for cross-disciplinary dialogue and inter-professional cooperation, which brings together the Italian design schools, who have gained considerable experience in the design and materials field. The network operates to make easier the collaboration among material scientists, engineers and designer, to connect stakeholders and the entrepreneurial world. It offers the possibility to explore the potential of emerging ambitions about materials, to move scientific research out of laboratories into market, guiding a design process in which unfinished scientific research became embodied in speculative designs to help enterprises value the public interest.

The network embodies into an integrated system the capabilities and the methods by the 4 teams in order to achieve a greater impact. This set of tools and methods constitutes, as a whole, the complex and dense dimension of the variables in selecting and designing materials as a design-driven innovation approach. We are briefly presenting the 4 methodologies:

- The Materials&Senses for Design methodology developed by the University of Rome is based on the parameterisation of the perceptive-sensory characteristics of materials. It works in close partnership with the Material&Scales methodology developed by the University of Bari (in the Soft Surfaces and Polisensoriality research group) in order to define specific scales of gradients obtained by classifying the visual, tactile, olfactory and acoustic properties that allow us to measure using scalar analysis (Lucibello, 2005; 2011; Carullo et al, 2013a; 2013b; 2014b; 2016c). In establishing scales of gradients (for example, from the hardest to the softest; from the most transparent to the most opaque and so on), a material's composition and the results

of perceptive variations mainly produced on the surface by processing procedures are both taken into consideration. Properly developed scales of gradients allow us to add important guideline criteria when designing materials, varying their perceptive-sensory features in an analytical way. The aim of the methodologies that have been fine-tuned by the two departments in Rome and Bari is to produce ‘palettes’ or ‘scales’ of materials and processing procedures that can be compared in order to scientifically guide the final material selection process depending on the product concept we intend to introduce to the market. In this way, we can avoid merely providing a list of possibilities from which to choose subjectively and seek that aspect of envisioning that is typical of design right from the start, which is thus positioned at the very heart of the scientific process of material production. Last but not least, the ‘palettes’ or ‘scales’ of materials function as a warehouse/archive of scientific importance for future possible uses of the materials produced. In this way, the integrated methodology of the two departments of Rome and Bari makes way for application processes typical of product design, rather than restricting them to one single final choice of a market-ready product;

- The Hybrid Design methodology developed by the research unit at Seconda Università degli Studi di Napoli is based on one-to-one collaboration between designers and scientists, in which roles and competences become hybrids through cross-pollination, thus making advances shared in mutual settings. Design and materials science come together as this relationship is explored through multiple perspectives, bringing fresh, new contributions to the culture of innovation (Langella, 2007, p. 61; 2003, p. 53). HDL’s methodological approach is based upon using design tools to interpret the technical and expressive opportunities offered by the innovation of materials and technologies. This interpretation is translated into new concepts, products, and systems of products and services capable of making the most of their specific properties and identities. A material’s identity is to be understood as the complex of opportunities, but also of limits and weaknesses, that characterize it and that must be elaborated in the form of a design in order to conceive applications in which the material expresses itself and can be exploited as effectively as possible. The identifying traits include environmental aspects, and such technical performance features as durability, processability, and mechanical properties, as well as those of insulation and barrier; also included are such perceptive traits as appearance, the ability to transmit and to reflect light, colour, and tactile properties (Langella et. al., 2012, pp. 85-88; Langella, 2003, p. 60). Using its own methodological and linguistic tools of multidisciplinary cooperation, the design experiments with the possibility of transferring and translating new design concepts belonging to new contemporary need scenarios into requirements to be proposed to materials scientists; these concepts must be able to keep up with the complexity of modern industrial production and its relationships with such cultural aspects as a setting’s productive history, human capital, and territorial assets;
- The DdMIM by MADEC is a systematic approach where both technical and humanistic skills are deeply engaged in the creative challenge to achieve material functionality and meanings ideas for disruptive innovation. The cross-disciplinary process integrates meta-design, material design and product design steps with the aim of orienting technological researches towards social innovation meanings. DdMIM is made up of 6 different steps of the R&D process. It starts with an open challenge by a

techno-scientific opportunity in the field of materials (a scientific discoveries, a patent, a new production process or a business problem to solve). The first steps are “data collection” and “sensing”, where the researchers analyse the initial data (technical constraints and marketing opportunities) to understand the background. Then, in the “sensemaking” phase, they start to envision applications scenarios, to outline a “vision of matter” that allows defining the user experience, on which profiling materials and product lines design. The sensemaking phase converges to product concepts, to defining material qualities, performance and behaviours to be developed on the basis of technological platforms (specifying phase). Then a “design discourse” contributes to define the design process. Once material and products designs are defined, it’s time to go into the prototyping step, followed by the storytelling step, in order to make clear the message of innovation for costumers (“setting up” phase). Finally, after an assessment step, the design process is finalized with its strategy, which contributes to material positioning inside the market.

The intersection, hybridization and subsequent evolutions of these approaches as a whole, are being the Design4Materials network added values.

Through joint research and educational activity, Design4Materials will trigger these methodologies in a unique method progressively tested and developed with characteristics of repeatability and circularity, covering the whole wide spectrum of design-oriented material project.

2.4 Potentials of the network

Design4Materials thus has applicative potential in terms of both method and merit.

Method because the network makes it possible to produce innovation through an approach that, in Italy, has yet to take on dimensions shared at the level of the various currently existing research efforts on materials.

Merit because this synergy produces innovation, as shown by the positive outcome of certain initiatives already developed by the Network, such as for example participation in the Research Project entitled POR/FERS 2007/2013 Coresearch “collaborative R&D project by Lazio’s SMEs”, entitled “GoSounDesign,” and the MAIND/PON03PE_000004_1 project “Materiali eco-innovativi e tecnologie avanzate per l’INDustria Manifatturiera delle costruzioni. M.M.L. Mediterranean Material Library” and the PON research project in the START UP tender, along with HUBspa “C.H.E.E.S.E.” Cultural Heritage Emotional Experience See-through Eyewear.

The Design4Materials network’s upcoming objectives include organizing a Workshop in collaboration with Istituto di Tecnologia di Genoa, in order to develop the identities of soft materials and their potential in applicative terms. The Workshop will be held in September 2017 at the laboratories of Genoa’s Fondazione IIT with a small group of 8 young designers, and will see the involvement of the affected companies. An initial reconnaissance of the typological as well as aesthetic/expressive potential that can be obtained from the chosen materials will allow a project brief to be defined, both for possible variants of the material and for its possible applications, thus clarifying the potential in terms of innovation. The results of the Workshop will be disseminated through the involvement of some Italian museums, such as Plart Foundation, Museo della Plastica in Naples, and/or MAXXI in Rome.

3. Conclusions

This network of design innovation starting from materials has the objective of transforming the individual local networks of university research into a national network, by creating synergy between the individual methodologies in order to build a “circular” system that in practice forges an active link between Science and Design.

Design4Materials has thus activated a process of strengthening the cultural and economic value of Italian research, by initiating synergistic collaborations between a strategic sector for Italian-made quality, design, and the excellence of Italian scientific research. This strengthening is obtained through hybridization and cross-fertilization among diverse and complementary disciplines and fields of research. This sets in motion a virtuous circle, from Science to Design: a bridge linking materials science, the world of production, and the final user, by cross-breeding methods and tools of scientific research with those typical of research in the field of design. The most tangible results include using design to capitalize on new materials and material systems yet to see industrial application, through experimentation to develop applicative scenarios and concepts for new products capable of conveying their innovative capacity while triggering a virtuous process that can in turn generate material innovation thanks to the envisioning capacities of design.

The direct impacts, in terms of spreading knowledge, are also corroborated by the experiments done in a teaching environment with students in university Design degree and PhD courses.

This theorized model (narrative database) highlights the relationships that exist between materials and sensory, and channels their potential in terms of product innovation.

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