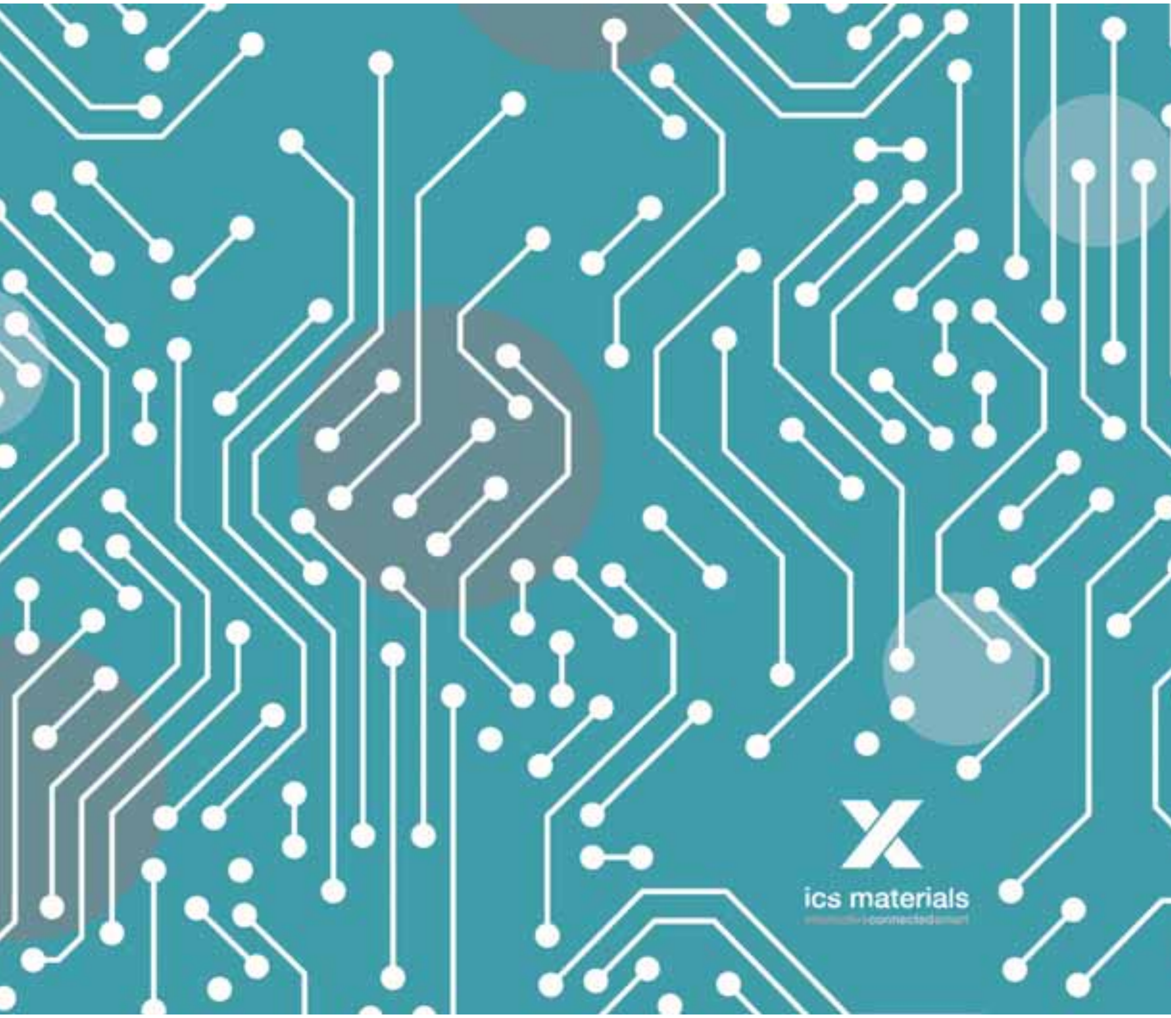
ICS MATERIALS

Interactive, connected, and smart materials

edited by Valentina Rognoli and Venere Ferraro



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1. The need of a systematic method to design for ICS Materials

As presented in the previous chapters of this book, Interactive Connected Smart (ICS) Materials are an emerging area of materials and technologies that are experimentally – or can be potentially – introduced in some fields of application, from responsive architecture to smart objects. In some sectors such as textiles, examples of ICS Materials not only are more likely to be seamlessly integrated due to satisfactory technical requirements – e.g., the degree of required miniaturization and flexibility of technologies – and the technological and manufacturing apparatus that allows seamless integration. Some practitioners already started to develop their own procedures to explore and design with and for materials with interactive, smart and connective characteristics. However, to enable them to design with and for ICS Materials and introduce them in their design practice, a systematic methodology with methods and tools made on purpose are required.

This methodology can also be used as a way to inform designers and to transfer knowledge to them. This is particularly relevant if we consider the field of education, where some experimental activities have been carried out using specific approaches, methods, and tools. By allowing both practitioners and students to explore, learn, ideate and develop about these materials, not only we transfer knowledge, but we build and reinforce skills and capabilities. These will contribute to the establishment of new kinds of professional profiles able to manage such materials and to advise companies for their integration.

In the chapter, we depict the State of the Art, with a broad survey on Material Design methods and tools involving interactive, connected, and smart materials. We mainly focus on design education, a field where more experimental approaches are applied and then exposed through publications. Then, we introduce the 'Design for ICS Materials' method and its supporting tools developed in the scope of the project 'ICS Materials'.

2. Approaches, tools, and methods (for learning how) to design interactive, connected, and smart materials: State of the Art

Before setting up a new method for designing for ICS Materials, we drafted the State of the Art, focusing on approaches, methods, and tools applied in design processes and learning environments. Indeed, in design education, some teaching activities have already been experimentally carried out to explore and apply these materials in different sectors. Although these experiences are still relatively recent and experimental, it is possible to recognize precise design and teaching methods, approaches, and tools that have been applied to transfer knowledge, experiment, ideate and develop a design with interactive, connected, and smart materials. Among these methodologies, some of them are focusing specifically on materials with interactive, connective, and smart characteristics (e.g., smart materials, smart material composites, tangible interactive surfaces, e-textiles), while others address generically to emerging material, including ICS Materials, but not limited to. We present a selection of design process and teaching experiences identified from the literature review and based on our experience as educators, pointing out at the most relevant observations on the approaches, methods and tools that have been applied. For a broader review of design teaching methods, we invite you to read (Parisi, 2020).

Mixed sources for learning and understanding ICS Materials. One of the most applied approach to gain knowledge about materials is the *mixed approach* (Haug, 2018), combining multiple learning sources. Examples of these sources are direct experimentation with materials, reading texts, watching videos, and discussions with peers, instructors, and experts. Tangible materials samples are efficient tools to gain understanding about novel materials and stimulate the creative process through direct manipulation (Haug, 2018; Rognoli, 2010; Pedgley, 2010; Ayala Garcia, Quijiano and Ruge, 2011). In this respect, one of the problematic issues when dealing with advanced materials – including ICS Materials – is that physical samples might be not easily accessible. Therefore, it is fundamental to provide designers and students with the opportunity to understand ICS Materials in the absence of physical samples. Examples in education show tutors replacing samples with other alterative learning materials in the format of databases (Hölter et al., 2019) and in the format of canvases or cards (Colombo, 2014). Considering the novelty of ICS Materials, other principal sources for gaining and sharing information and inspirations are open-access platforms presenting case studies, instructions, and tutorials, like *Materiability* (http://materiability.com) by Manuel Kretzer and Openmaterials (http://openmaterials.org) by Catarina Mota.

Kretzer (2017) argues that it is a priority that designers acquire active material literacy before applying them, including learning how to use and qualify their potential. The suggested learning approach is through multi-disciplinarity, hands-on explorations, digital fabrication, access to open-source information and technologies, and development of speculative and critical applications. Similar approaches are shared within the *FabricAdemy* program (https://textile-academy.org), coordinated by Anastasia Pistofidou (FabTextiles / Iaac FabLab BCN) and Cecilia Raspanti (TextileLab Amsterdam / Waag Technology & Society).

The role of application and contextualization. The methods presented in these pages are fundamentally embedding *Active learning* (Bonwell and Eison, 1991). In material education for design, students are often engaged within a design challenge or a project brief, as it conventionally happens in practice.

This denotes a tendency towards *application-oriented* design processes in education and training programmes for designers. These methods are based on the application of the materials into a product, to challenge their limits and potentials, and promote new product development and innovation. Often, they involve stakeholder, for examples companies, to contextualize the materials and reinforce the connection between Academia and Industry (Piselli et al., 2018). Another common approach is *context-driven*. The context – whether it is an industrial sector, a situation, or a broader social scenario – is defined as a starting point of the design process and provides borders to the limitless possibilities of ICS Materials. In a context, ICS Materials and their resulting application will be situated in a discourse with industry and society involving not only technological limitations and opportunities but also social necessities. Indeed, one challenge related to ICS Materials arises from a significant risk of developing a product embedding an emerging material or technology, without creating a real value for society.

On these lines, the Design-driven Material Innovation Methodology (Dd-MIM) (Lecce and Ferrara, 2016) is a systematic approach for design students and practitioners, research centres, and small-medium enterprises, based on the understanding of the broader socio-cultural scenario before selecting advanced materials, including smart ones. It allows the development of one or more materials starting from scientific discoveries, material patents, or production processes, to identify scenarios of application and to develop new products. DdMIM has been used in the application of smart materials and interactive technologies for tangible interfaces in products and interiors in design workshops at the School of Design of the Politecnico di Milano (Ferrara and Russo, 2019).

Speculative and critical design approach. Some other methods are based on a *speculative design approach* using critical thinking and prototyping to question technological, societal, and ethical implications of advanced materials and technologies in future scenarios. By envisioning and projecting future development and application of ICS Materials, this approach overcomes their evident current technological limitations and scarce availability. In this respect, Barati et al. (2015) argue that "designer's naïve perspective with respect to every technical detail of a technology allows them to see new applications." One example of speculative design method in the context of smart materials is the *Dystopian Thinking*. It uses science fiction-based scenarios as a starting point to generate ideas of smart materials wearable applications in future or alternative situations[1]. The design process was supported by a toolkit based on inspirational cards and canvases.

With a more hands-on approach, the InDATA project team at the Design Department of the Politecnico di Milano (http://www.indata.polimi.it) carried out an experimental design activity in the format of the Hackathon "Data < > Materials". The design process was focused on developing interactive devices and wearables by combining speculative design, do-it-yourself bioplastic making, electronics programming and embedding, and digital fabrication with the support of the Fab Lab environment (Parisi et al., 2021). The design process used future scenarios involving the use of technologies as a starting point and was facilitated with mixed learning and design tools with the aim of understanding materials and technologies and carry out material experimentation, concept ideation, and prototyping.

On these lines, another design approach is the one applied b young designers and students at the Institute for MaterialDesign IMD at the Offenbach University of Arts and Design (http://imd-materialdesign.com). There, they are dealing with active material systems, augmented with digital, adaptive or interactive components. The design process is based on hands-on exploration and prototyping of materials demonstrators, working in a hybrid design

[1] El Futuro de los Wearables Dinamicos / the Future of Dynamic Wearables" (http://blog.materfad.com/2018/02/materfad-organiza-un-workshop-sobre-wearables-en-la-mobile-week-barcelona-2018; https://www.piscolabisdesigners.org/workshop-future-of-wearables-from-dystopian-thinking-x-jessica-fernandez-cano).

space where form, material, and technology overlap. The results of this hybrid practice are prototypes encouraging the discussion about material authenticity and speculative applications (Parisi, Holzbach and Rognoli, 2020).

In the workshops *Coded Bodies* (https://codedbodies.com/), interaction designer Giulia Tomasello engage companies, design practitioners and students in a design process combining traditional textile techniques, sensing and actuating technologies, smart materials and biological textiles to develop a speculative concept and prototype physical soft wearables, adaptive structures, and active second skins.

Multi-disciplinary approaches. The urgency for creating a multi-disciplinary environment to learn, experiment and develop applications of ICS Materials is expressed in a large number of cases. Indeed, ICS Materials area is mainly situated in the intersection between design, materials, and interaction, practically involving electronic circuits design and material crafting, along with design capabilities. Since only a few cases report to actually operate in this multi-disciplinary field with co-tutoring or cross-field collaborations (Schmid, Rümelin and Richter, 2013), this is a still major gap. The project *Datemats* proposes a training methodological framework for companies, design practitioners and students to design with and for four areas of emerging materials and technologies, including ICS Materials. This framework is characterized by cross-disciplinarity for understanding, shaping, and applying these materials (Ferraro and Parisi, 2020).

Cross-disciplinary knowledge includes sustainability. The design process used at the *Interactive Organisms Lab* coordinated by Katia Vega focuses on exploring sustainable interactive objects and wearables starting from hands-on exploration with organic and growing materials (mycelium) in combination with interactive technologies (Vasquez, Lazaro and Vega, 2019).

Experiential learning through material-centred approach. An approach that is fundamentally embedded in design practice and education is *Experiential learning* (Kolb, 1984). This approach allows designers to gain procedural knowledge about novel materials by learning through making (Pedgley, 2010). Most of the mentioned methods emphasize direct experimentation through exercises and hands-on exploration. *Material tinkering* is a goal free and playful exploration with physical components – both materials and technologies – for understanding their potentials and guiding further developments (Rognoli and Parisi, 2021; Parisi, Rognoli and Sonneveld, 2017; Santulli and Rognoli, 2020; Alarcón et al., 2020; Asbjørn Sörensen, 2018). Schön and Bennet (1996) described how the design process could be approached as a conversation with materials, through which the practitioner gets to know the materials.

On these lines, the *Enactive Environments Lab* (http://www.enactiveenvironments.com/) founded by Karmen Franinović reflects on the direct exploration of responsive and active materials (Franinović and Frankze, 2019) in creative research processes as a negotiation with materials – with their form, behaviours, and interaction as one – rather than imposing ideas and forms on them. Creative hands-on exploration using analog and digital materials, tools, and methods, as well as the experience of the user enhance embodied and situated knowledge engaged in both tacit and creative process and physical interaction.

Therefore, it becomes necessary to create methods based on the central role of materials in the design process. Often one material or a selection of materials are the starting point of the design process. This is the case for the *Material Driven Design (MDD) method* developed by Karana, Barati, Rognoli and Zeeuw van der Lann (2015). Practicing this method, practitioners and students start from a material at hand and design for materials experience (Karana, Pedgley and Rognoli, 2014), by tuning their physical qualities, sensory profile, emotional and meanings associations. This method targets novel materials with yet limited applications and unrecognizable identities – including ICS Materials – to foster meaningful materials experiences and ultimately materials acceptance by the society and the market. The method was applied on designing with and for intelligent composite materials, specifically an underdeveloped piezoelectric and light-emitting smart composite material (Barati, Giaccardi and Karana, 2018; Barati, Karana and Foole, 2017; Barati, Karana and Hekkert, 2015; Barati et al., 2015).

Simulation techniques replacing physical samples and inspiring forms and interactions. One of the problematic issues of designing and teaching for ICS Materials is often the scarce access not only to materials samples, but also to equipment, facilities, and multi-disciplinary environments to experiment and produce prototypes. Instead, simulation can be used to exemplify or mimic the sensory qualities or the physical behaviours of the intended material by creating, collecting, and combining other material samples (Karana et al., 2015). Metaphors and analogies can be used to inspire and communicate the performance and behaviours of smart and interactive materials. Experience prototyping and bodystorming techniques can be used to physically explore, test, and define the functionality and performances of ICS materials in the early stages of the design process or in the absence of physical materials or equipment (Piselli et al., 2015).

Even in hands-on experiences, metaphors can be used to inspire forms and behaviours in the ideation phase. This is the case of the design process applied by Schmid, Rümelin, and Richter (2013) focused on the development of glass-based tangible user interface, starting from the suggestions provided by the glass forms and qualities which are then implemented with electronics.

User-centred approaches. The user interaction and expectations in relation to the material aesthetics and performances are essential, both considering physical body involvement and emotional engagement. In the design process described by Russo and Ferrara (2017), the role of the whole-body experience and somaesthetics was vital in ideating with interactive materials. In another case (Colombo, 2014), the role of user experience in dealing with smart-material based interactive products is emphasized in the use of tools for enhancing product sensory experience. Like the afore-described MDD method, these processes are fundamentally user-centred, considering the user involved since the initial stages, often through user studies.

3. The 'Design for ICS Materials' method

Starting from this survey on methods, tools, and approaches, we defined a tentative method to design for ICS Materials. The method is addressed to design students and practitioners, or to mixed-students classes and multi-disciplinary teams, including design expertise. The objectives of the method are listed as follow.

- To understand ICS Materials components, architecture, and capabilities, using inspirational best examples and encouraging a mixed-method learning approach
- To engage students and practitioners in an active and experiential learning process with a design challenge or project brief
- To encourage multi-disciplinary collaborations within a mixed group
- To provide a scenario, context, or situation as a starting point to drive the exploration of opportunities and, then, the ideation of a solution (case-specific and context-driven approaches)
- To envision future scenarios for ICS Materials using a speculative approach
- To support the ideation of design solutions integrating ICS Materials with an application-oriented approach
- To explore and identify the experiential qualities of the solution when interacting with the user, encouraging a user-centred approach.
- The method has a flexible structure that can be integrated into design

activities, courses, and short workshops focused on different application sectors and design challenges. The main phases of the method are 1) Exploration, 2) Definition, 3) Conceptualization, and 4) Integration. A demonstration and description of the stages is contained in the previous chapter (Chapter 3.5). For the pilot application of the methodology, no hands-on activities involving materials and making techniques were provided. The main reasons are the scarce availability of needed materials and technologies, as well as the limited timeframe imagined for the initial application of the method. Therefore, instead of a hands-on approach, we opted for replacing physical materials with a toolkit of descriptive materials using textual and visual information, and we encourage a simulation approach, using analytic tools such as maps, schemes, descriptions, and creative tools visualization, mood-board, collages, and sketches.

4. The 'Design for ICS Materials' toolkit

As for the method, the supporting toolkit is a flexible and modular set of tools that can be adapted to different applications that can vary according to the timeframe, participants, structure, and application field. For the description of the toolkit, we may use examples of contents from the first application of the methodology in the workshop NautICS Materials (Parisi et al., 2019a; 2019 b), described in this book (Chapter 3.5). The tentative version of the toolkit to support the methodology is composed of three elements, as follows.

Reference scenarios. Scenarios are the starting point of the design process. They represent a context, a situation, an issue (for instance an environmental or social problem), or a field of application. The context can be more or less broad, more concrete or abstract, established/present or future/speculative. They vary according to the topic and aim of the activity. They can be provided through visual and textual contents, for example, with boards of images and mood boards supported with a title, description, and references. One example of scenarios boards is presented in the previous chapter, basing on potential Yachting scenarios. In that case, each scenario was presented through an inspirational A4 board providing a mood board, textual storytelling, and different keywords. This tool is used mainly in the Exploration phase.

ICS Material Cards. A deck of 48 cards was designed with the purpose to help students and designers understand all the elements of ICS Materials and build new concepts with them. With the cards, by gain an understanding of what ICS Materials are, how they are made, how they work, and how they appear, and identify their inputs and outputs of interaction. Each card shows an example of ICS Material, with pictures and textual information, i.e., name of the project, name of the author, a short text describing how it functions and performs, and a graphical schematic representation showing its components divided into layers, inputs, and outputs (Fig. 1 and Fig. 2). To do that each example was deconstructed into its constituting elements. The examples that have been selected by the authors to build the cards deck encompassed materials, surfaces, and material-based objects and systems used in many applications, with different behaviours, complexity, and technological readiness levels. This tool can be used in the Exploration stage, for learning and informing activities by reading the content of the cards. Also, it can be used in the Definition phase, by clustering them and selecting the most relevant and promising examples according to the scenario.

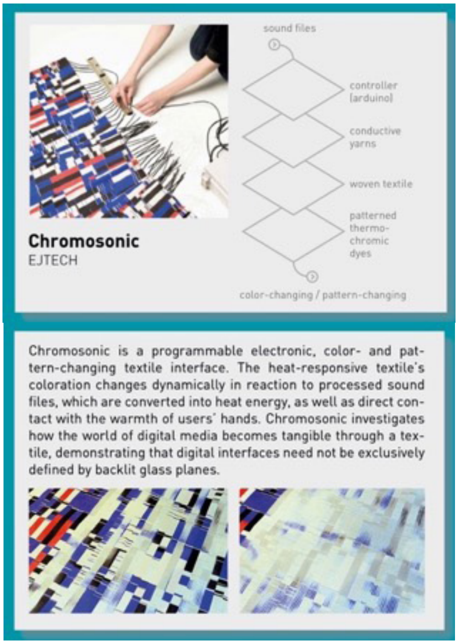

Fig. 1 - ICS Material Card of the case Chromosonic by EJtech (front and retro)

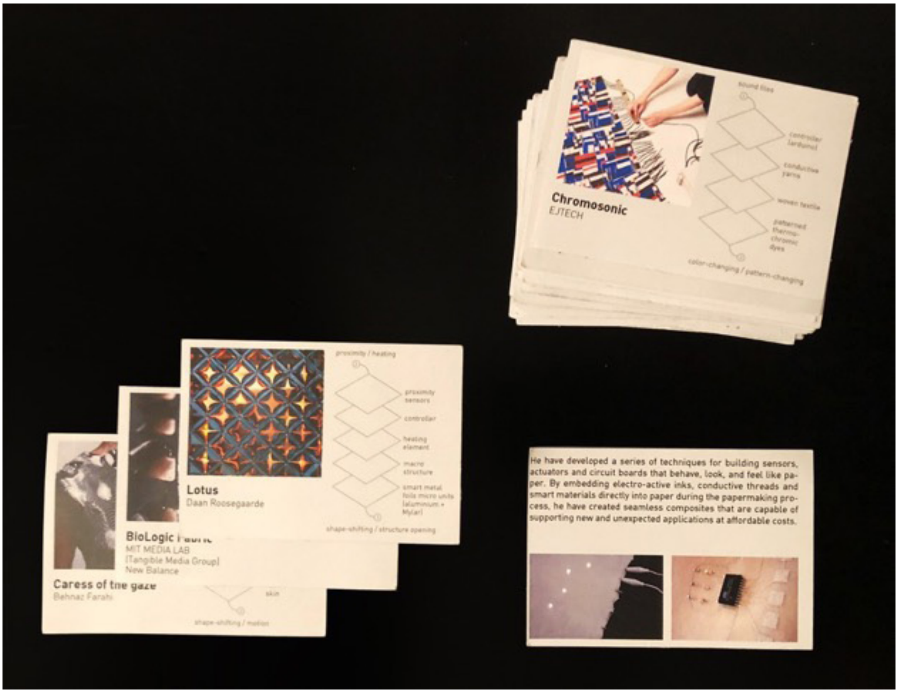

Fig. 2 - A selection of ICS Materials Cards

Concept Canvas. A Concept Canvas in A3 size was designed to be used mainly in the Conceptualization and Integration phases (Fig. 3). The purpose of the canvas is to guide students and designers through the novel design method to conceptualize a new ICS Material. The canvas was divided into three sections, namely (i) material system building, (ii) material system sketching, and (iii) material system description. The first section provides an empty schematic graphical representation of a material system divided into layers with blank spaces to complete with the names of components, input, and output. This recalls the same design used in the cards. The purpose is to use the scheme to build a novel material system by getting inspirations from the examples shown in the ICS Materials Cards and combining their constituting elements in a new coherent design. Although the scheme represents a simplified laminate construction, other ways of integrating and combining elements in a composite structure may be considered. The second section provided a blank box where students and designers can start materializing the first concept idea with sketching, collages of pictures, or mixed techniques. The third section asks to outline the concept with textual technical description ('how it works'), performative description ('what it does'), sensory and experiential description ('how it feels, looks, and sounds; which emotions, meaning associations, and actions are elicited'), basing on the layers of Materials Experience framework (Giaccardi and Karana, 2015). This last section aims to reflect upon the performances and experiences enabled and implied by the concept, based on the individual material components and the composition of them in an articulated system. Even if we suggest to follow the steps sequentially, the three activities can be carried out in parallel with an iterative approach, as each section informs the others.

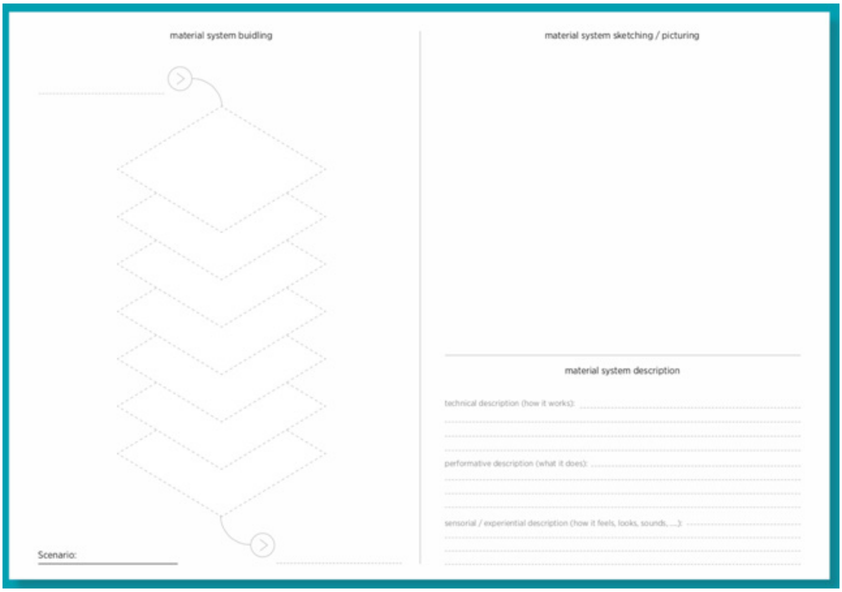

Fig. 3 - ICS Material Concept Canvas

5. Conclusion and final remarks on the method

In this chapter, we presented the need for a systematic method for designing for ICS Materials and for teaching how to design for ICS Materials. State of the Art on methods, tools, and approaches is presented by literature review, with the main focus on education in design. The method, its objectives, phases, and supporting tools are described. In the previous chapter (3.5), a pilot application of the methodology in the design education context is described: the workshop "NautICS Materials" (Parisi et al., 2019a; 2019b). The workshop used the context of the nautical sector and related environmental inputs and triggers – for example, moisture, light, movement and sound – as the starting point for a multidisciplinary design workshop on ICS Materials using the here proposed method and supporting toolkit to design in the absence of physical materials. The workshop approached the topic with a speculative perspective, acknowledging that such materials are quite advanced for the current yacht sector, but could be potentially applied in concepts of future yachts. Besides this pilot experience, the method and tools can be transferred to other sectors or to scale up in larger experimental and applied actions – not only in education, but also in practice with industrial partners – for the integration of smart materials and technologies in the design space.

The method may prove its potential in guiding the design phases from the material understanding, to the new materials conceptualization, and their integration into design concepts. Among the elements of the toolkit, the cards may overcome the limitations caused by the lack of physical samples of the actual materials and provid immediate and effective information on the materials. However, future development of the methodology may integrate material samples and prototyping.

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This present book covers a series of outstanding reputation researchers' contributions on the topic of ICS Materials: a new class of emerging materials with properties and qualities concerning interactivity, connectivity and intelligence. In the general framework of **ICS Materials**' domain, each chapter deals with a specific aspect following the characteristic perspective of each researcher. As result, methods, tools, guidelines emerged that are relevant and applicable to several contexts such as product, interaction design, materials science and many more.

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